THE OUTLINE OF SCIENCE

ERRATA

Page 5. Diagram. The "day" of Mercury *should read* "88 days." The orbit of Saturn *should read* "29½ years."

Page 8. Underline to portrait of Professor J. C. Adams. *For* "Neptune" in line 3 *read* "Uranus."

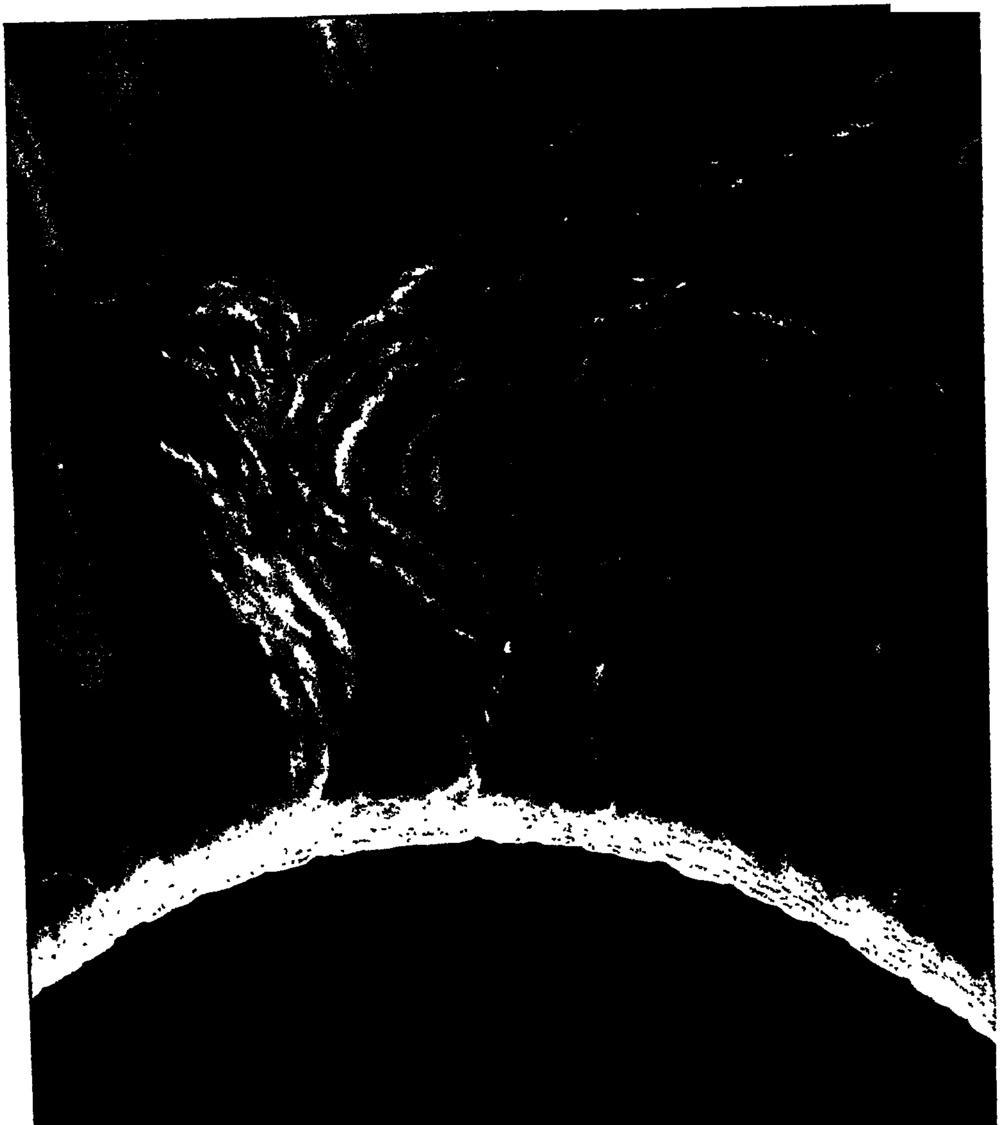
Page 9. Underline to Figure 6. After May 29, 1919, *add* "taken at Sobral, Brazil."

Page 22. Right-hand col., line 24. Sentence beginning "But" and ending "white heat" on page 23 *should read:* "But as the crowded meteors approach the sun the speed increases."

Page 72, line 33 and § 4, cut in note. *For* "nebulæ" *read* "nebula."

Plate facing page 176. 7th line of underline. *For* "twenty-five-thousandth part of an inch" *read* "the three-millionth part of an inch."

Page 180. Underline to illustration, 4th line. *For* "less than half a cubic inch" *read* "less than a fifteenth of a cubic inch."



THE GREAT SCARLET SOLAR PROMINENCES, WHICH ARE SUCH A NOTABLE FEATURE OF THE SOLAR PHENOMENA, ARE IMMENSE OUTBURSTS OF FLAMING HYDROGEN RISING SOMETIMES TO A HEIGHT OF 500,000 MILES (see page 9)

THE OUTLINE OF SCIENCE

A PLAIN STORY SIMPLY TOLD

EDITED BY

PROFESSOR
J. ARTHUR THOMSON

VOLUME ONE

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CONTENTS OF VOLUME ONE

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PAGE

LIST OF COLOUR PLATES

THE OUTLINE OF SCIENCE

INTRODUCTION

THERE is abundant evidence of a widened and deepened interest in modern science. How could it be otherwise when we think of the magnitude and the eventfulness of recent advances?

But the interest of the general public would be even greater than it is if the makers of new knowledge were more willing to expound their discoveries in ways that could be "understanded of the people." No one objects very much to technicalities in a game or on board a yacht, and they are clearly necessary for terse and precise scientific description. It is certain, however, that they can be reduced to a minimum without sacrificing accuracy, when the object in view is to explain "the gist of the matter." So this OUTLINE OF SCIENCE is meant for the general reader, who lacks both time and opportunity for special study, and yet would take an intelligent interest in the progress of science which is making the world always new.

The story of the triumphs of modern science is one of which Man may well be proud. Science reads the secret of the distant star and anatomises the atom; foretells the date of the comet's return and predicts the kinds of chickens that will hatch from a dozen eggs; discovers the laws of the wind that bloweth where it listeth and reduces to order the disorder of disease. Science is always setting forth on Columbus voyages, discovering new worlds and conquering them by understanding. For Knowledge means Foresight, and Foresight means Power.

The idea of Evolution has influenced all the sciences, forcing us to think of *everything* as with a history behind it, for we have travelled far since Darwin's day. The solar system, the earth, the mountain ranges, and the great deeps, the rocks and crystals, the plants and animals, man himself and his social institutions—all must be seen as the outcome of a long process of Becoming. There are some eighty-odd chemical elements on the earth to-day, and it is now much more than a suggestion that these are the outcome of an inorganic evolution, element giving rise to element, going back and back to some primeval stuff, from which they were all originally derived, infinitely long ago. No idea has been so powerful a tool in the fashioning of New Knowledge as this simple but profound idea of Evolution, that the present is the child of the past and the parent of the future. And with the picture of a continuity of evolution from nebula to social systems comes a promise of an increasing control—a promise that Man will become not only a more accurate student, but a more complete master of his world.

It is characteristic of modern science that the whole world is seen to be more vital than before. Everywhere there has been a passage from the static to the dynamic. Thus the new revelations of the constitution of matter, which we owe to the discoveries of men like Professor Sir J. J. Thomson, Professor Sir Ernest Rutherford, and Professor Frederick Soddy, have shown the very dust to have a complexity and an activity heretofore unimagined. Such phrases as "dead" matter and "inert" matter have gone by the board.

The new theory of the atom amounts almost to a new conception of the universe. It bids fair to reveal to us many of nature's hidden

secrets. The atom is no longer the indivisible particle of matter it was once understood to be. We know now that there is an atom within the atom—that what we thought was elementary can be dissociated and broken up. The present-day theories of the atom and the constitution of matter are the outcome of the comparatively recent discovery of such things as radium, the X-rays, and the wonderful revelations of such instruments as the spectroscope and other highly perfected scientific instruments.

The advent of the electron theory has thrown a flood of light on what before was hidden or only dimly guessed at. It has given us a new conception of the framework of the universe. We are beginning to know and realise of what matter is made and what electric phenomena mean. We can glimpse the vast stores of energy locked up in matter. The new knowledge has much to tell us about the origin and phenomena, not only of our own planet, but other planets, of the stars, and the sun. New light is thrown on the source of the sun's heat; we can make more than guesses as to its probable age. The great question to-day is: is there *one* primordial substance from which all the varying forms of matter have been evolved?

But the discovery of electrons is only one of the revolutionary changes which give modern science an entrancing interest.

As in chemistry and physics, so in the science of living creatures there have been recent advances that have changed the whole prospect. A good instance is afforded by the discovery of the "hormones," or chemical messengers, which are produced by ductless glands, such as the thyroid, the supra-renal, and the pituitary, and are distributed throughout the body by the blood. The work of physiologists like Professor Starling and Professor Bayliss has shown that these chemical messengers regulate what may be called the "pace" of the body, and bring about that regulated harmony and smoothness of working which we know as health. It is not too much to say that the discovery of hormones has changed the whole of physiology. Our knowledge of the human body far surpasses that of the past generation.

The persistent patience of microscopists and technical improvements like the "ultra-microscope" have greatly increased our knowledge of the invisible world of life. To the bacteria of a past generation have been added a multitude of microscopic *animal* microbes, such as that which causes Sleeping Sickness. The life-histories and the weird ways of many important parasites have been unravelled; and here again knowledge means mastery. To a degree which has almost surpassed expectations there has been a revelation of the intricacy of the stones and mortar of the house of life, and the microscopic study of germ-cells has wonderfully supplemented the epoch-making experimental study of heredity which began with Mendel. It goes without saying that no one can call himself educated who does not understand the central and simple ideas of Mendelism and other new departures in biology.

The procession of life through the ages and the factors in the sublime movement; the peopling of the earth by plants and animals and the linking of life to life in subtle inter-relations, such as those between flowers and their insect-visitors; the life-histories of individual types and the extraordinary results of the new inquiry called "experimental embryology"—these also are among the subjects with which this OUTLINE will deal.

The behaviour of animals is another fascinating study, leading to a provisional picture of the dawn of mind. Indeed, no branch of science surpasses in interest that which deals with the ways and habits—the truly wonderful devices, adaptations and instincts—of insects, birds, and mammals. We no longer deny a degree of intelligence to some members of the animal world—even the line between intelligence and reason is sometimes difficult to find.

Fresh contacts between physiology and the study of man's mental life; precise studies of the ways of children and wild peoples; and new methods like those of the psycho-analysts must also receive the attention they deserve, for they are giving us a "New Psychology" and the claims of psychical research must also be recognised by the open-minded.

The general aim of the OUTLINE is to give the reader a clear and concise view of the essentials of present-day science, so that he may follow with intelligence the modern advance and share appreciatively in man's continued conquest of his kingdom.

J. ARTHUR THOMSON.

I

THE ROMANCE OF THE HEAVENS

THE SCALE OF THE UNIVERSE—THE SOLAR SYSTEM

LAPLACE.
One of the greatest mathematical astronomers of all time and originator of the nebular theory.

§ 1

THE story of the triumphs of modern science naturally opens with Astronomy. The picture of the Universe which the astronomer offers to us is imperfect; the lines he traces are often faint and uncertain. There are many problems which have been solved, there are just as many about which there is doubt, and, notwithstanding our great increase in knowledge, there remains just as many which are entirely unsolved. "The problem of the structure and duration of the universe," said the great astronomer Simon Newcomb, "is the most far-reaching with which the mind has to deal. Its solution may be regarded as the ultimate object of stellar astronomy, the possibility of reaching which has occupied the minds of thinkers since the beginning of civilisation. Before our time the problem could be considered only from the imaginative or the speculative point of view. Although we can to-day attack it to a limited extent by scientific methods, it must be admitted that we have scarcely taken more than the first step toward the actual solution. . . . What is the duration of the universe in *time*? Is it fitted to last for ever in its present form, or does it contain within itself the seeds of dissolution? Must it, in the course of time, in we know not how many millions of ages, be transformed into something very different from what it now is? This question is intimately associated with the question whether the stars form a system. If they do, we may suppose that system to be permanent in its general features; if not, we must look further for our conclusions."

The Heavenly Bodies.

The heavenly bodies fall into two very distinct classes so far as their relation to our Earth is concerned; the one class, a very small one, comprises a sort of colony of which the Earth is a member. These bodies are called *planets*, or wanderers. There are eight of them, including the Earth, and they all circle round the sun. Their names, in the order of their distance from the sun, are Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, and of these Mercury, the nearest to the sun, is rarely seen by the naked eye. Uranus is practically invisible, and Neptune quite so. These eight planets, together with the sun, constitute, as we have said, a sort of little colony; this colony is called the Solar System.

The second class of heavenly bodies are those which lie *outside* the solar system. Every one of those glittering points we see on a starlit night is at an immensely greater distance from us than is any member of the Solar System. Yet the members of this little colony of ours, judged by terrestrial standards, are at enormous distances from one another. If a shell were shot in a straight line from one side of Neptune's orbit to the other it would take five hundred years to complete its journey. Yet this distance, the greatest in the Solar System, is

insignificant compared to the distances of the stars. One of the nearest stars to the earth that we know of is Alpha Centauri, estimated to be some twenty-five billions of miles away. Sirius, the brightest star in the firmament, is double this distance from the earth.

We must imagine the colony of planets to which we belong as a compact little family swimming in an immense void. At distances which would take our shell, not hundreds, but millions of years to traverse, we reach the stars—or rather, a star, for the distances between stars are as great as the distance between the nearest of them and our Sun. The Earth, the planet on which we live, is a mighty globe bounded by a crust of rock many miles in thickness; the great volumes of water which we call our oceans lie in the deeper hollows of the crust. Above the surface an ocean of invisible gas, the atmosphere, rises to a height of about three hundred miles, getting thinner and thinner as it ascends.

FIG. 1.—THE MOON ENTERING THE SHADOW CAST BY THE EARTH.
The diagram shows the Moon partially eclipsed.

Except when the winds rise to a high speed, we seem to live in a very tranquil world. At night, when the glare of the sun passes out of our atmosphere, the stars and planets seem to move across the heavens with a stately and solemn slowness. It was one of the first discoveries of modern astronomy that this movement is only apparent. The apparent creeping of the stars across the heavens at night is accounted for by the fact that the earth turns upon its axis once in every twenty-four hours. When we remember the size of the earth we see that this implies a prodigious speed.

In addition to this the earth revolves round the sun at a speed of more than a thousand miles a minute. Its path round the sun, year in year out, measures about 580,000,000 miles. The earth is held rigidly to this path by the gravitational pull of the sun, which has a mass 333,432 times that of the earth. If at any moment the sun ceased to exert this pull the earth would instantly fly off into space straight in the direction in which it was moving at the time, that is to say, at a tangent. This tendency to fly off at a tangent is continuous. It is the balance between it and the sun's pull which keeps the earth to her almost circular orbit. In the same way the seven other planets are held to their orbits.

Circling round the earth, in the same way as the earth circles round the sun, is our moon. Sometimes the moon passes directly between us and the sun, and cuts off the light from us. We then have a total or partial eclipse of the sun. At other times the earth passes directly between the sun and the moon, and causes an eclipse of the moon. The great ball of the earth naturally trails a mighty shadow across space,

and the moon is "eclipsed" when it passes into this.

The other seven planets, most of which have moons of their own, circle round the sun as the earth does. The sun's mass is immensely larger than that of all the planets put together, and all of them would be drawn into it and perish if they did not travel rapidly round it in gigantic orbits. So the eight planets, spinning round on their axes, follow their fixed paths round the sun. The planets are secondary bodies, but they are most important, because they are the only globes in which there can be life, as we know life.

If we could be transported in some magical way to an immense distance in space above the sun, we should see our Solar System as it is drawn in the accompanying diagram (Fig. 2), except that the planets would be mere specks, faintly visible in the light which they receive from the sun. If we moved still farther away, billions of miles away, the planets would fade entirely out of view, and the sun would shrink into a point of fire, a star. And here you begin to realise the nature of the universe. *The sun is a star. The stars are suns.* Our sun looks big simply because of its comparative nearness to us. The universe is a stupendous collection of millions of stars or suns, many of which may have planetary families like ours.

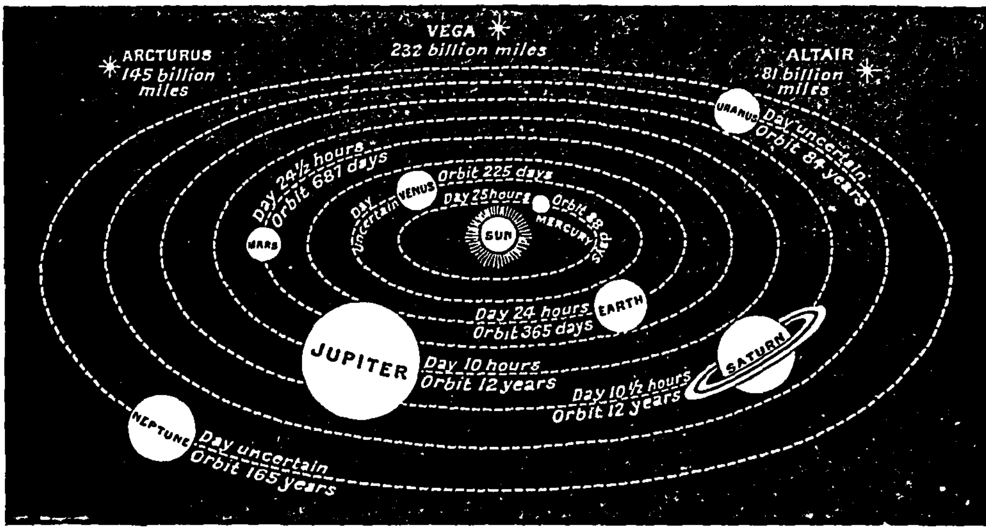


FIG. 2.—A DIAGRAM OF THE SOLAR SYSTEM.

Neptune's "year," it will be noted, is 165 times our year. It will be seen that the Stars in the diagram are at enormous distances, showing the great isolation in space of the Solar System.

§ 2

The Scale of the Universe.

How many stars are there? A glance at a photograph of star-clouds will tell at once that it is quite impossible to count them. The fine photograph reproduced on the next page (Fig. 3) represents a very small patch of that pale-white belt, the Milky Way, which spans the sky at night. It is true that this is a particularly rich area of the Milky Way, but the entire belt of light has been resolved in this way into masses or clouds of stars. Astronomers have counted the stars in typical districts here and there, and from these partial counts we get some idea of the total number of stars. There are estimated to be between two and three thousand million stars.

Yet these worlds are separated by inconceivable distances from each other, and it is one of the greatest triumphs of modern astronomy to have mastered, so far, the scale of the universe. For several centuries astronomers have known the relative distances from each other of the sun and the planets. If they could discover the actual distance of any one

planet from any other, they could at once tell all the distances within the Solar System.

The sun is, on the latest measurements, 92,830,000 miles from the earth. This means that in six months from now the earth will be right at the opposite side of its path round the sun, or 185,000,000 miles away from where it is now. Viewed or photographed from two positions so wide apart, the nearest stars show a tiny "shift" against the background of the most distant stars, and that is enough for the mathematician. He can calculate the distance of any star near enough to show this "shift." We have found that the nearest star to the earth, a recently discovered star, is twenty-two billion miles away. Only thirty stars are known to be within a hundred billion miles of us.

This way of measuring does not, however, take us very far away in the heavens. There are only a few hundred stars within five hundred billion miles of the earth, and at that distance the "shift" of a star against the background (parallax, the astromer calls it) is so minute that figures are very uncertain. At this point the astronomer takes up a new method. He learns the different types of stars, and then he is able to deduce more or less accurately the distance of a star of a known type from its faintness. He, of course, has instruments for gauging their light. As a result of twenty years work in this field, it is now known that the more distant stars of the Milky Way are at least a hundred thousand billion miles away from the sun.

Photo: Harvard College Observatory.

FIG. 3.—THE MILKY WAY.
Note the cloud-like effect.

Our sun is in a more or less central region of the universe, or a few hundred billion miles from the actual centre. The remainder of the stars, which are all outside our Solar System, are spread out, apparently, in an enormous disc-like collection, so vast that even a ray of light, which travels at the rate of 186,000 miles a second, would take 50,000 years to travel from one end of it to the other. This, then, is what we call our universe.

Are there other Universes?

Why do we say "our universe"? Why not *the* universe? It is now believed by many of our most distinguished astronomers that our colossal family of stars is only one of many universes. By a universe an astronomer means any collection of stars which are close enough to controleach other's movements by gravitation; and it is clear that there might be many universes, in this sense, separated from each other by profound abysses of space. Probably there are.

For a long time we have been familiar with certain strange objects in the heavens which are called "spiral nebulæ" (Fig. 4). We shall see at a later stage what a nebula is, and we shall see that some astronomers regard these spiral nebulæ as worlds "in the making." But some of the most eminent astronomers believe that they are separate universes—"island-universes" they call them—or great collections of millions of stars like our universe. There are certain peculiarities in the structure of the Milky Way which lead these astronomers to think that

our universe may be a spiral nebula, and that the other spiral nebulæ are "other universes."

Vast as is the Solar System, then, it is excessively minute in comparison with the Stellar System, the universe of the Stars, which is on a scale far transcending anything the human mind can apprehend.

THE SOLAR SYSTEM

THE SUN

§ 1

But now let us turn to the Solar System, and consider the members of our own little colony.

Within the Solar System there are a large number of problems that interest us. What is the size, mass, and distance of each of the planets? What satellites, like our Moon, do they possess? What are their temperatures? And those other, sporadic members of our system, comets and meteors, what are they? What are their movements? How do they originate? And the Sun itself, what is its composition, what is the source of its heat, how did it originate? Is it running down?

These last questions introduce us to a branch of astronomy which is concerned with the physical constitution of the stars, a study which, not so very many years ago, may well have appeared inconceivable. But the spectroscope enables us to answer even these questions, and the answer opens up questions of yet greater interest. We find that the stars can be arranged in an order of development—that there are stars at all stages of their life-history. The main lines of the evolution of the stellar universe can be worked out. In the sun and stars we have furnaces with temperatures enormously high; it is in such conditions that substances are resolved into their simplest forms, and it is thus we are enabled to obtain a knowledge of the most primitive forms of matter. It is in this direction that the spectroscope (which we shall refer to immediately) has helped us so much. It is to this wonderful instrument that we owe our knowledge of the composition of the sun and stars, as we shall see. "That the spectroscope will detect the millionth of a milligram of matter, and on that account has discovered new elements, commands our admiration; but when we find in addition that it will detect the nature of forms of matter billions of miles away, and moreover, that it will measure the velocities with which these forms of matter are moving with an absurdly small per cent. of possible error, we can easily

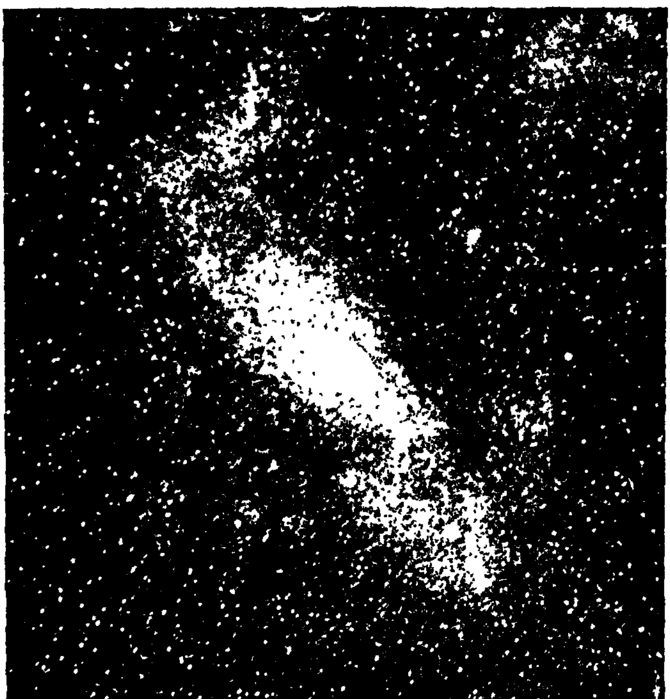


Photo: Royal Observatory, Greenwich.

FIG. 4.—NEBULA IN ANDROMEDA, SEPT. 23, 1898.

A famous Spiral Nebula, sometimes visible to the naked eye.

acquiesce in the statement that it is the greatest instrument ever devised by the brain and hand of man."

Such are some of the questions with which modern astronomy deals. To answer them requires the employment of instruments of almost incredible refinement and exactitude and also the full resources of mathematical genius. Whether astronomy be judged from the point of view of the phenomena studied, the vast masses, the immense distances, the æons of time, or whether it be judged as a monument of human ingenuity, patience, and the rarest type of genius, it is certainly one of the grandest, as it is also one of the oldest, of the sciences.

The Solar System.

In the Solar System we include all those bodies dependent on the sun which circulate round it at various distances, deriving their light and heat from the sun—the planets and their moons, certain comets and a multitude of meteors: in other words, all bodies whose movements in space are determined by the gravitational pull of the sun.

The Sun.

Thanks to our wonderful modern instruments and the ingenious methods used by astronomers, we have to-day a remarkable knowledge of the sun.

Look at the figure of the sun in the frontispiece. The picture represents an eclipse of the sun; the dark body of the moon has screened the sun's shining disc and taken the glare out of our eyes; we see a silvery halo surrounding the great orb on every side. It is the sun's atmosphere, or "crown" (corona) stretching for millions of miles into space in the form of a soft silvery-looking light; probably much of its light is sunlight reflected from particles of dust, although the spectroscope shows an element in the corona that has not so far been detected anywhere else in the universe and which in consequence has been named Coronium.

We next notice in the illustration that at the base of the halo there are red flames peeping out from the edges of the hidden disc. When one remembers that the sun is 866,000 miles in diameter, one hardly needs to be told that these flames are really gigantic. We shall see what they are presently.

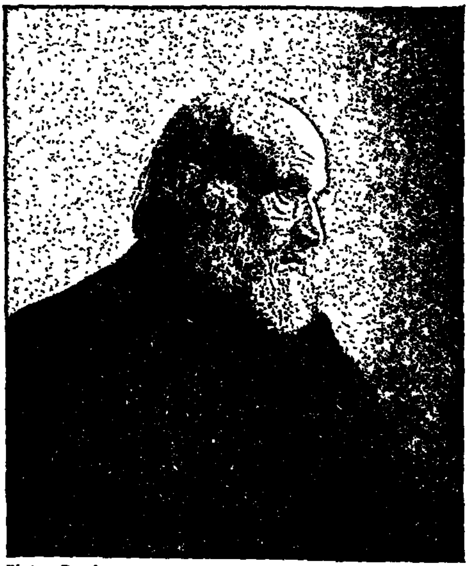


Photo: Royal Astronomical Society.

PROFESSOR J. C. ADAMS,

who, anticipating the great French mathematician, Le Verrier, discovered the planet Neptune by calculations based on the irregularities of the orbit of Neptune. One of the most dramatic discoveries in the history of Science.

Regions of the Sun.

The astronomer has divided the sun into definite concentric regions or layers. These layers *envelop the nucleus* or central body of the sun somewhat as the atmosphere envelops our earth. It is through these vapour layers that the bright white body of the sun is seen. Of the innermost region, the heart or nucleus of the sun, we know almost nothing. The central body or nucleus is surrounded by a brilliantly luminous envelope or layer of vaporous matter which is what we see when we look at the sun and which the astronomer calls the photosphere.

Above—that is, overlying—the photosphere there is a second layer of glowing gases, which is known as the reversing layer. This layer is cooler than the underlying photosphere; it forms a veil of smoke-like haze and is of from 500 to 1,000 miles in thickness.

A third layer or envelope immediately lying over the last one is the region known as the chromosphere. The chromosphere extends from 5,000 to 10,000 miles in thickness—a "sea" of red tumultuous surging fire. Chief among the glowing gases is the vapour of hydrogen.

The intense white heat of the photosphere beneath shines through this layer, overpowering its brilliant redness. From the uppermost portion of the chromosphere great fiery tongues of glowing hydrogen and calcium vapour shoot out for many thousands of miles, driven outward by some prodigious expulsive force. It is these red "prominences" which are such a notable feature in the picture of the eclipse of the sun already referred to.

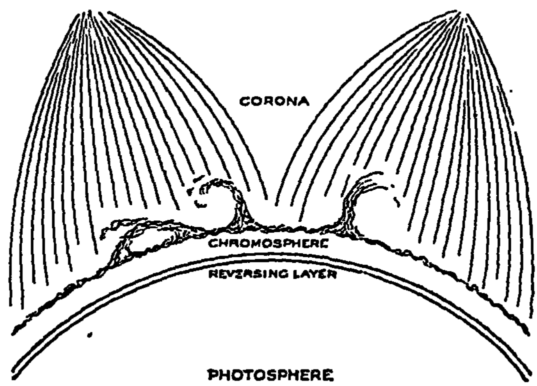


FIG. 5.—DIAGRAM SHOWING THE MAIN LAYERS OF THE SUN. Compare with frontispiece.

During the solar eclipse of 1919 one of these red flames rose in less than seven hours from a height of 130,000 miles to more than 500,000 miles above the sun's surface. This immense column of red-hot gas, four or five times the thickness of the earth, was soaring upward at the rate of 60,000 miles an hour.

These flaming jets or prominences shooting out from the chromosphere are not to be seen every day by the naked eye; the dazzling light of the sun obscures them, gigantic as they are. They can be observed, however, by the spectroscope any day, and they are visible to us for a very short time during an eclipse of the sun. Some extraordinary outbursts have been witnessed. Thus the late Professor Young described one on September 7, 1871, when he had been examining a prominence by the spectroscope:

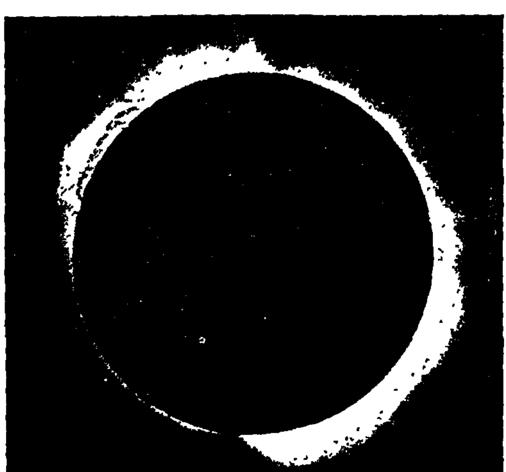


Photo: Royal Observatory, Greenwich.

FIG. 6—SOLAR PROMINENCES SEEN AT TOTAL SOLAR ECLIPSE, MAY 29, 1919.

The small Corona is also visible.

"It had remained unchanged since noon of the previous day—a long, low, quiet-looking cloud, not very dense, or brilliant, or in any way remarkable except for its size. At 12.30 a.m. the Professor left the spectroscope for a short time, and on returning half an hour later to his observations, he was astonished to find the gigantic Sun flame shattered to pieces. The solar atmosphere was filled with flying debris, and some of these portions reached a height of 100,000 miles above the solar surface. Moving with a velocity which, even at the distance of 93,000,000 miles, was almost perceptible to the eye, these fragments doubled their height in ten minutes. On January 30, 1885, another distinguished solar observer, the late Professor Tacchini of Rome, observed one of the greatest prominences ever seen by man. Its height was no less than 142,000 miles—eighteen times the diameter of the earth. Another mighty flame was so vast that supposing the eight large planets of the solar system ranged one on top of the other, the prominence would still tower above them."[1]

The fourth and uppermost layer or region is that of the corona, of immense extent and fading away into the surrounding sky — this

[1] *The Romance of Astronomy*, by H. Macpherson.

we have already referred to. The diagram (Fig. 5) shows the dispositions of these various layers of the sun. It is through these several transparent layers that we see the white light body of the sun.

§ 2

The Surface of the Sun.

Here let us return to and see what more we know about the photosphere — the sun's surface. It is from the photosphere that we have gained most of our knowledge of the composition of the sun, which is believed not to be a solid body. Examination of the photosphere shows that the outer surface is never at rest. Small bright cloudlets come and go in rapid succession, giving the surface, through contrasts in luminosity, a granular appearance. Of course, to be visible at all at 92,830,000 miles the cloudlets cannot be small. They imply enormous activity in the photosphere. If we might speak picturesquely the sun's surface resembles a boiling ocean of white-hot metal vapours. We have to-day a wonderful instrument, which will be described later, which dilutes, as it were, the general glare of the sun, and enables us to observe these fiery eruptions at any hour. The " oceans " of red-hot gas and white-hot metal vapour at the sun's surface are constantly driven by great storms. Some unimaginable energy streams out from the body or nucleus of the sun and blows its outer layers into gigantic shreds, as it were.

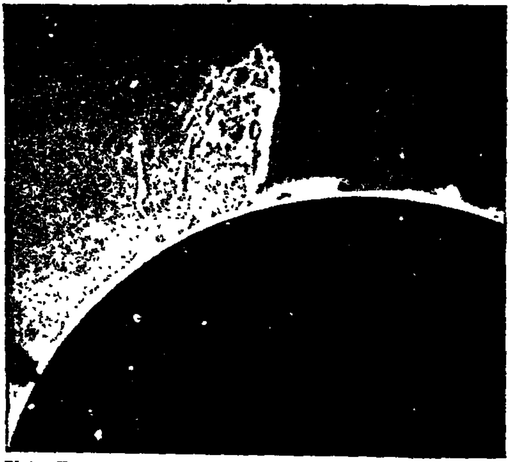


Photo: Kodaikanal Observatory, South India.

FIG. 7.—SOLAR PROMINENCES, MAY 26, 1916.

These flames are sometimes hundreds of thousands of miles high.

The actual temperature at the sun's surface, or what appears to us to be the surface—the photosphere—is, of course, unknown, but careful calculation suggests that it is from 5,000° C. to 7,000° C. The interior is vastly hotter. We can form no conception of such temperatures as must exist there. Not even the most obdurate solid could resist such temperatures, but would be converted almost instantaneously into gas. But it would not be gas as we know gases on the earth. The enormous pressures that exist on the sun must convert even gases into thick treacly fluids. We can only infer this state of matter. It is beyond our power to reproduce it.

Sun-spots.

It is in the brilliant photosphere that the dark areas known as sun-spots appear. Some of these dark spots—they are dark only by contrast with the photosphere surrounding them—are of enormous size, covering many thousands of square miles of surface. What they are we cannot positively say. They look like great cavities in the sun's surface. Some think they are giant whirlpools. Certainly they seem to be great whirling streams of glowing gases with vapours above them and immense upward and downward currents within them. Round the edges of the sun-spots rise great tongues of flame.

Perhaps the most popularly known fact about sun-spots is that they are somehow connected with what we call magnetic storms on earth. These magnetic storms manifest themselves in interruptions of our telegraphic and telephonic communications, in violent disturbances of the mariner's compass, and in exceptional auroral displays. The connection between the two sets of phenomena cannot be doubted, even although at times there may be a great spot on the sun without any corresponding " magnetic storm " effects on the earth.

A surprising fact about sun-spots is that they show definite periodic variations in number. The best-defined period is one of about eleven years. During this period the spots increase to a maximum in number and then diminish to a minimum, the variation being more or less regular. Now this can only mean one thing. To be periodic the spots must have some deep-seated connection with the fundamental facts

of the sun's structure and activities. Looked at from this point of view their importance becomes great.

It is from the study of sun-spots that we have learned that the sun's surface does not appear to rotate all at the same speed. The "equatorial" regions are rotating quicker than regions further north or south. A point forty-five degrees from the equator seems to take about two and a half days longer to complete one rotation than a point on the equator. This, of course, confirms our belief that the sun cannot be a solid body.

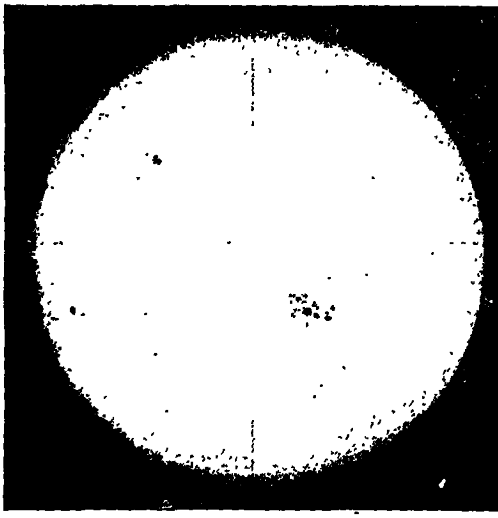


Photo: Royal Observatory, Greenwich.

FIG. 8.—SUN, FEB. 5, 1905.

A general view of the Sun showing Sun-spots.

What is its composition? We know that there are present, in a gaseous state, such well-known elements as sodium, iron, copper, zinc, and magnesium; indeed, we know that there is practically every element in the sun that we know to be in the earth. How do we know?

It is from the photosphere, as has been said, that we have won most of our knowledge of the sun. The instrument used for this purpose is the spectroscope; and before proceeding to deal further with the sun and the source of its energy it will be better to describe this instrument.

A WONDERFUL INSTRUMENT, AND WHAT IT REVEALS

The spectroscope is an instrument for analysing light. So important is it in the revelations it has given us that it will be best to describe it fully. Every substance to be examined must first be made to glow, made luminous; and as nearly everything in the heavens *is* luminous the instrument has a great range in Astronomy. And when we speak of analysing light, we mean that the light may be broken up into waves of different lengths. What we call light is a series of minute waves in ether, and these waves are—measuring them from crest to crest, so to say—of various lengths. Each wave-length corresponds to a colour of the rainbow. The shortest waves give us a sensation of violet colour, and the largest waves cause a sensation of red. The rainbow, in fact, is a sort of natural spectroscope. (The meaning of the rainbow is that the moisture-laden air has sorted out these waves, in the sun's light, according to their length.) Now the simplest form of spectroscope is a glass prism—a triangular-shaped piece of glass. If white light (sunlight, for example) passes through a glass prism, we see a series of rainbow-tinted colours. Anyone can notice this effect when sunlight is shining through any kind of cut glass—the stopper of a wine decanter, for instance. If, instead of catching with the eye the coloured lights as they emerge from the glass prism, we allow them to fall on a screen, we shall find that they pass, by continuous gradations, from red at the one end of the screen, through orange, yellow, green, blue, and indigo, to violet at the other end. *In*

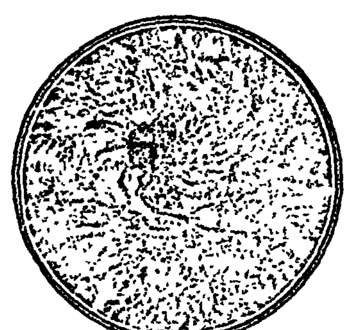


FIG. 9.—A SUN-SPOT AS THE 100-INCH TELESCOPE ON MOUNT WILSON SHOWS IT. Notice the flaky appearance of the surface of the Sun surrounding the spot

other words, what we call white light is composed of rays of these several colours. They go to make up the effect which we call white. And now just as water can be split up into its two elements, oxygen and hydrogen, so sunlight can be broken up into its primary colours, which are those we have just mentioned.

This range of colours, produced by the spectroscope, we call the solar spectrum, and these are, from the spectroscopic point of view, primary colours. Each shade of colour has its definite position in the spectrum. That is to say, the light of each shade of colour (corresponding to its wave-length) is reflected through a certain fixed angle on passing through the glass prism. Every possible kind of light has its definite position, and is denoted by a number which gives the wave-length of the vibrations constituting that particular kind of light.

Now, other kinds of light besides sunlight can be analysed. Light from any substance which has been made incandescent may be observed with the spectroscope in the same way, and each element can be thus separated. It is found that each substance (in the same conditions of pressure, etc.) gives a constant spectrum of its own. *Each metal displays its own distinctive colour. It is obvious, therefore, that the spectrum provides the means for identifying a particular substance.* It was by this method that we discovered in the sun the presence of such well-known elements as sodium, iron, copper, zinc, and magnesium.

Every chemical element known, then, has a distinctive spectrum of its own when it is raised to incandescence, and this distinctive spectrum is as reliable a means of identification for the element as a human face is for its owner. Whether it is a substance glowing in the laboratory or in a remote star makes no difference to the spectroscope; if the light of any substance reaches it, that substance will be recognised and identified by the characteristic set of waves.

The spectrum of a glowing mass of gas will consist in a number of bright lines of various colours, and at various intervals; corresponding to each kind of gas, there will be a peculiar and distinctive arrangement of bright lines. But if the light from such a mass of glowing gas be made to pass through a cool mass of the *same* gas it will be found that dark lines replace the bright lines in the spectrum, the reason for this being that the cool gas absorbs the rays of light emitted by the hot gas. Experiments of this kind enable us to reach the important general statement that every gas, when cold, absorbs the same rays of light which it emits when hot.

Crossing the solar spectrum are hundreds and hundreds of dark lines. These could not at first be explained, because this fact of discriminative absorption was not known. We understand now. The sun's white light comes from the photosphere, but between us and the photosphere there is, as we have seen, another solar envelope of relatively cooler vapours—the reversing layer. Each constituent element in this outer envelope stops its own kind of light, that is, the kind of light made by incandescent atoms of the same element in the photosphere. The "stoppages" register themselves in the solar spectrum as dark lines placed exactly where the corresponding bright lines would have been. The explanation once attained, dark lines became as significant as bright lines. The secret of the sun's composition was out. We have found practically every element in the sun that we know to be in the earth. We have iden ified an element in the sun before we were able to isolate it on the earth. We have been able even to point to the coolest places on the sun, the centres of sun-spots, where alone the temperature seems to have fallen sufficiently low to allow chemical compounds to form.

It is thus we have been able to determine what the stars, comets, or nebulæ are made of.

A Unique Discovery.

In 1868 Sir Norman Lockyer detected a light coming from the prominences of the sun which was not given by any substance known on earth, and attributed this to an unknown gas which he called helium, from the Greek *helios*, the sun. *In 1895 Sir William Ramsay discovered in certain minerals the same gas identified by the spectroscope.* We can say, therefore, that this gas was discovered in the sun nearly thirty years before it was found on earth; this discovery of the long-lost heir is as thrilling a chapter in the detective story of science as any in the sensational stories of the day, and makes us feel quite certain that our methods really tell us

of what elements sun and stars are built up. The light from the corona of the sun, as we have mentioned, indicates a gas still unknown on earth, which has been christened Coronium.

Measuring the Speed of Light.

But this is not all; soon a new use was found for the spectroscope. We found that we could measure with it the most difficult of all speeds to measure, speed in the line of sight. Movement at right angles to the direction in which one is looking is, if there is sufficient of it, easy to detect, and, if the distance of the moving body is known, easy to measure. But movement in the line of vision is both difficult to detect and difficult to measure. Yet, even at the enormous distances with which astronomers have to deal, the spectroscope can detect such movement and furnish data for its measurement. If a luminous body containing, say, sodium is moving rapidly towards the spectroscope, it will be found that the sodium lines in the spectrum have moved *slightly from their* usual definite positions towards the violet end of the spectrum, the amount of the change of position increasing with the speed of the luminous body. If the body is moving away from the spectroscope the shifting of the spectral lines will be in the opposite direction, towards the red end of the spectrum. In this way we have discovered and measured movements that otherwise would probably not have revealed themselves unmistakably to us for thousands of years. In the same way we have watched, and measured the speed of, tremendous movements on the sun, and so gained proof that the vast disturbances we should expect there actually do occur.

Photo: Elliott & Fry, Ltd.

PROFESSOR EDDINGTON.

Professor of Astronomy at Cambridge. The most famous of the English disciples of Einstein.

IS THE SUN DYING?

§ 3

Now let us return to our consideration of the sun.

To us on the earth the most patent and most astonishing fact about the sun is its tremendous energy. Heat and light in amazing quantities pour from it without ceasing.

Where does this energy come from? Enormous jets of red glowing gases can be seen shooting outwards from the sun, like flames from a fire, for thousands of miles. Does this argue fire as we know fire on the earth? On this point the scientist is sure. The sun is not burning, and combustion is not the source of its heat. Combustion is a chemical reaction between atoms. The conditions that make it possible are known and the results are predictable and measurable. But no chemical reaction of the nature of combustion as we know it will explain the sun's energy, nor indeed will any ordinary chemical reaction of any kind. If the sun were composed of combustible *material* throughout and the conditions of combustion as we understand them were always present, the sun would burn itself out in some thousands of years, with marked changes in its heat and light production as the process advanced. There is no evidence of such changes. There is, instead, strong evidence that the sun has been emitting light and heat in prodigious quantities, not for thousands, but for millions of years. Every addition to our knowledge that throws light on the sun's age seems to make for increase rather than decrease of its years. This makes the wonder of its energy greater.

And we cannot avoid the issue of the source of the energy by saying merely that the sun is

gradually radiating away an energy that originated in some unknown manner, away back at the beginning of things. Reliable calculations show that the years required for the mere cooling of a globe like the sun could not possibly run to millions. In other words, the sun's energy must be subject to continuous and more or less steady renewal. However it may have acquired its enormous energy in the past, it must have some source of energy in the present.

The best explanation that we have to-day of this continuous accretion of energy is that it is due to shrinkage of the sun's bulk under the force of gravity. Gravity is one of the most mysterious forces of nature, but it is an obvious fact that bodies behave as if they attracted one another, and Newton worked out the law of this attraction. We may say, without trying to go too deeply into things, that every particle of matter attracts every other throughout the universe. If the diameter of the sun were to shrink by one mile all round, this would mean that all the millions of tons in the outer one-mile thickness would have a straight drop of one mile towards the centre. And that is not all, because obviously the layers below this outer mile would also drop inwards, each to a less degree than the one above it. What a tremendous movement of matter, however slowly it might take place! And what a tremendous energy would be involved! Astronomers calculate that the above shrinkage of one mile all round would require fifty years for its completion, assuming, reasonably, that there is close and continuous relationship between loss of heat by radiation and shrinkage. Even if this were true we need not feel over-anxious on this theory; before the sun became too cold to support life many millions of years would be required.

It was suggested at one time that falls of meteoric matter into the sun would account for the sun's heat. This position is hardly tenable now. The mere bulk of the meteoric matter required by the hypothesis, apart from other reasons, is against it. There is undoubtedly an enormous amount of meteoric matter moving about within the bounds of the solar system, but most of it seems to be following definite routes round the sun like the planets. The stray erratic quantities destined to meet their doom by collision with the sun can hardly be sufficient to account for the sun's heat.

Recent study of radio-active bodies has suggested another factor that may be working powerfully along with the force of gravitation to maintain the sun's store of heat. In radio-active bodies certain atoms seem to be undergoing disintegration. These atoms appear to be splitting up into very minute and primitive constituents. But since matter may be split up into such constituents, may it not be built up from them?

The question is whether these "radio-active" elements are undergoing disintegration, or formation, in the sun. If they are undergoing disintegration—and the sun itself is undoubtedly radio-active—then we have another source of heat for the sun that will last indefinitely.

THE PLANETS

LIFE IN OTHER WORLDS?

§ 1

It is quite clear that there cannot be life on the stars. Nothing solid or even liquid can exist in such furnaces as they are. Life exists only on planets, and even on these its possibilities are limited. Whether all the stars, or how many of them, have planetary families like our sun, we cannot positively say. If they have, such planets would be too faint and small to be visible tens of billions of miles away. Some astronomers think that our sun may be exceptional in having planets, but their reasons are speculative and unconvincing. Probably a large proportion at least of the stars have planets, and we may therefore survey the globes of our own solar system and in a general way extend the results to the rest of the universe.

In considering the possibility of life as we know it we may at once rule out the most distant planets from the sun, Uranus and Neptune. They are probably too hot. We may also pass over the nearest planet to the sun, Mercury. We have reason to believe that it turns on its axis in the same period as it revolves round the sun, and it must therefore always present the same side to the sun. This means that the heat on the sunlit side of Mercury is above boiling-point, while the cold on the other

side must be between two and three hundred degrees below freezing-point.

The planet Venus, the bright globe which is known to all as the morning and evening "star,"

The Planet Venus.

seems at first sight more promising as regards the possibility of life. It is of nearly the same size as the earth and it has a good atmosphere, but there are many astronomers who believe that, like Mercury, it always presents the same face to the sun, and it would therefore have the same disadvantage—a broiling heat on the sunny side and the cold of space on the opposite side. We are not sure. The surface of Venus is so bright—the light of the sun is reflected to us by such dense masses of cloud and dust—that it is difficult to trace any permanent markings on it, and thus ascertain how long it takes to rotate on its axis. Many astronomers believe that they have succeeded, and that the planet always turns the same face to the sun. If it does, we can hardly conceive of life on its surface, in spite of the cloud-screen.

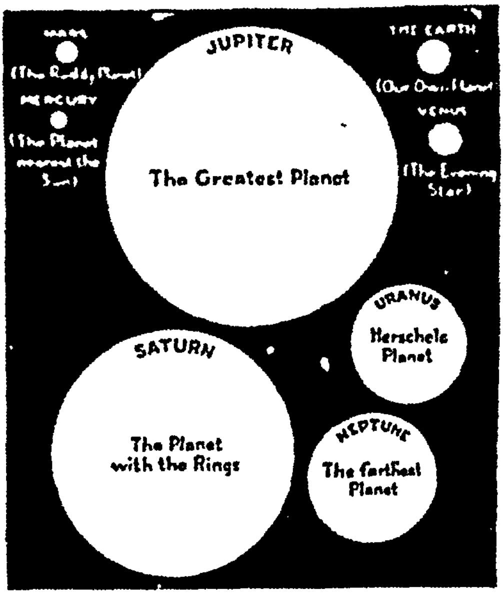


FIG. 10.—THE PLANETS, SHOWING THEIR RELATIVE DIMENSIONS

We turn to Mars; and we must first make it clear why there is so much speculation about life on Mars, and why it is supposed that, if there *is* life on Mars, it must be more advanced than life on the earth.

The basis of this belief is that if, as we saw, all the globes in our solar system are masses

Is there Life on Mars?

of metal that are cooling down, the smaller will have cooled down before the larger, and will be further ahead in their development. Now Mars is very much smaller than the earth, and must have cooled at its surface millions of years before the earth did. Hence, if a story of life began on Mars at all, it began long before the story of life on the earth. We cannot guess what sort of life-forms would be evolved in a different world, but we can confidently say that they would tend toward increasing intelligence; and thus we are disposed to look for highly intelligent beings on Mars.

But this argument supposes that the conditions of life, namely air and water, are found on Mars, and it is disputed whether they are found there in sufficient quantity. The late Professor Percival Lowell, who made a lifelong study of Mars, maintained that there are hundreds of straight lines drawn across the surface of the planet, and he claimed that they are beds of vegetation marking the sites of great channels or pipes by means of which the "Martians" draw water from their polar ocean. Professor W. H. Pickering, another high authority, thinks that the lines are long, narrow marshes fed by moist winds from the poles. There are certainly white polar caps on Mars. They seem to melt in the spring, and the dark fringe round them grows broader.

Other astronomers, however, say that they find no trace of water-vapour in the atmosphere of Mars, and they think that the polar caps may be simply thin sheets of hoar-frost or frozen gas. They point out that, as the atmosphere of Mars is certainly scanty, and the distance from the sun is so great, it may be too cold for the fluid water to exist on the planet.

If one asks why our wonderful instruments cannot settle these points, one must be reminded that Mars is never nearer than 34,000,000 miles from the earth, and only approaches to this distance once in fifteen or seventeen years. The

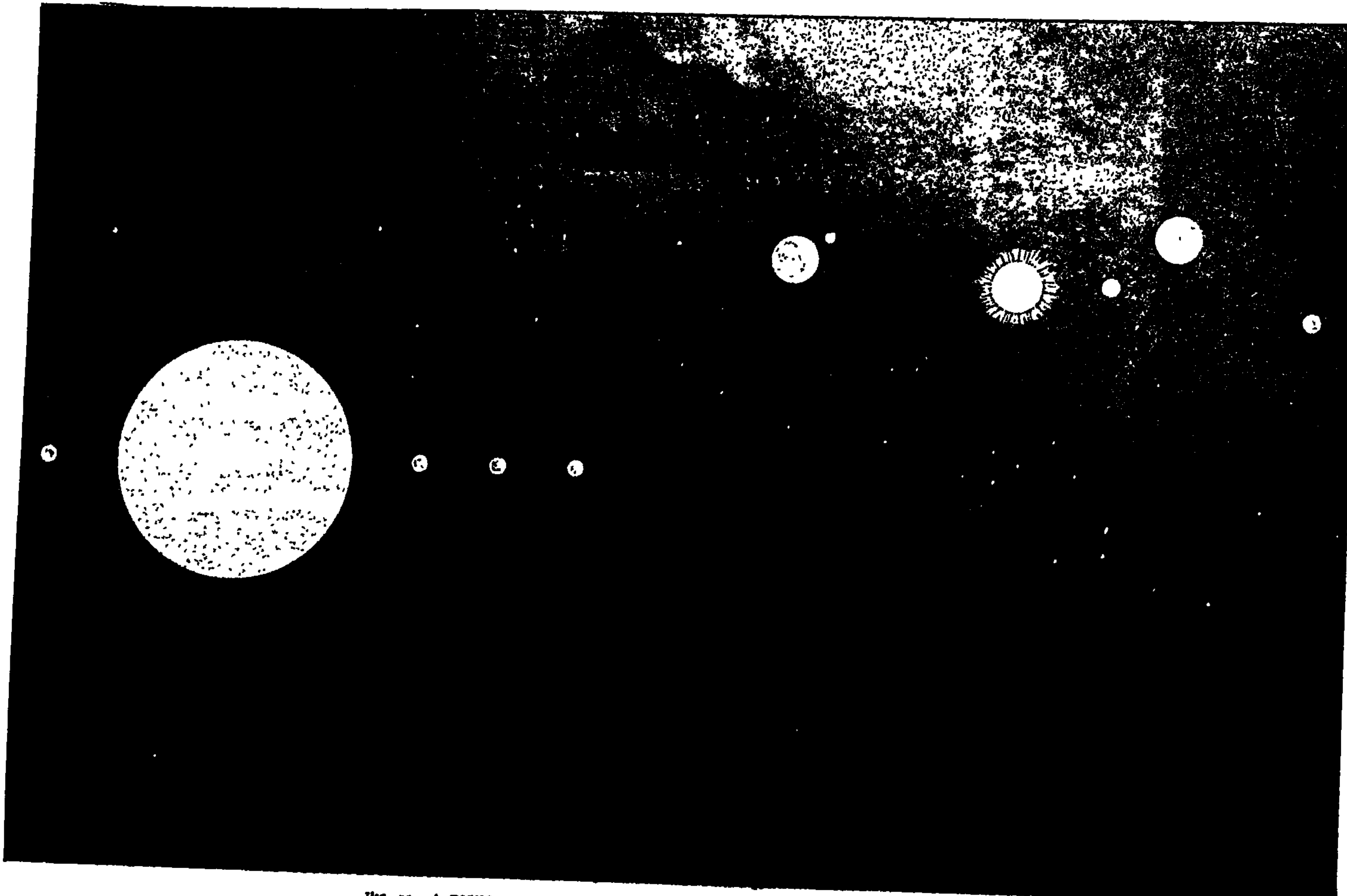


FIG. 11.—A PICTORIAL REPRESENTATION OF PART OF THE SOLAR SYSTEM.
Reading from left to right: Jupiter and four of its satellites, Earth, Moon, Sun, Mercury, Venus, and Mars.

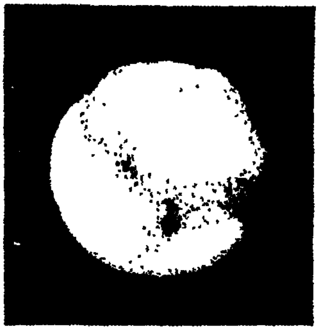


Photo: Mount Wilson Observatory.

FIG. 12.—MARS, OCTOBER 5, 1909.
Showing the dark markings and the Polar Cap.

image of Mars on the photographic negative taken in a big telescope is very small. Astronomers rely to a great extent on the eye, which is more sensitive than the photographic plate. But it is easy to have differences of opinion as to what the eye sees, and so there is a good deal of controversy.

In August 1924 the planet will again be well placed for observation, and we may learn more about it. Already a few of the much-disputed lines, which people wrongly call "canals," have been traced on photographs. Astronomers who are sceptical about life on Mars are often not fully aware of the extraordinary adaptability of life. There was a time when the climate of the whole earth, from pole to pole, was semi-tropical for millions of years. No animal could then endure the least cold, yet now we have plenty of Arctic plants and animals. If the cold came slowly on Mars, as we have reason to suppose, the population could be gradually adapted to it. On the whole, it is possible that there is advanced life on Mars, and it is not impossible, in spite of the very great difficulties of a code of communication, that our "elder brothers" may yet flash across space the solution of many of our problems.

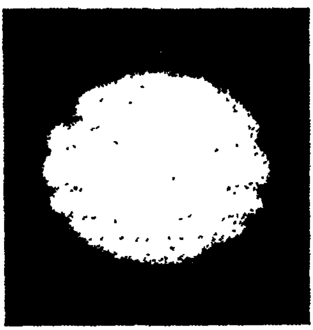


FIG. 13.—JUPITER.
Showing the belts which are probably cloud formations.

§ 2

Next to Mars, going outward from the sun, is Jupiter. Between Mars and Jupiter, however, there are more than three hundred million miles of space, and the older astronomers wondered why this was not occupied by a planet. We now know that it contains about nine hundred "planetoids," or small globes of from five to five hundred miles in diameter. It was at one time thought that a planet might have burst into these fragments (a theory which is not mathematically satisfactory), or it may be that the material which is scattered in them was prevented by the nearness of the great bulk of Jupiter from uniting into one globe.

Jupiter and Saturn.

For Jupiter is a giant planet, and its gravitational influence must extend far over space. It is 1,300 times as large as the earth, and has nine moons, four of which are large, in attendance on it. It is interesting to note that the outermost moons of Jupiter and Saturn revolve round these planets in a direction contrary to the usual direction taken by moons round planets, and by planets round the sun. But there is no life on Jupiter.

The surface which we see in photographs (Fig. 13) is a mass of cloud or steam which always envelops the body of the planet. It is apparently red-hot. A red tinge is seen sometimes at the edges of its cloud-belts, and a large red region (the "red spot"), 23,000 miles in length, has been visible on it for half a century. There may be a liquid or solid core to the planet, but as a whole it is a mass of seething vapours whirling round on its axis once in every ten hours. As in the case of the sun, however, different latitudes appear to rotate at different rates. The interior of Jupiter is very hot, but the planet is not self-luminous. The planets Venus and Jupiter shine very brightly, but they have no light of their own; they reflect the sunlight.

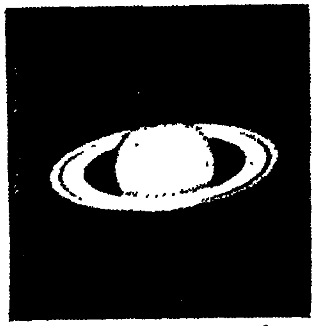


Photo: Professor E. E. Barnard, Yerkes Observatory.

FIG. 14.—SATURN, NOVEMBER 19, 1911.
Showing the rings, mighty swarms of meteorites.

Saturn is in the same interesting condition. The surface in the photograph (Fig. 14) is steam, and Saturn is so far away from the sun that the vaporisation of its oceans must necessarily be due to its own internal heat. It is too hot for water to settle on its surface. Like Jupiter, the great globe turns on its axis once in ten hours—a prodigious speed—and must be a swirling, seething mass of metallic vapours and gases. It is instructive to compare Jupiter and Saturn in this respect with the sun. They are smaller globes and have cooled down more than the central fire.

Saturn is a beautiful object in the telescope because it has ten moons (to include one which is disputed) and a wonderful system of "rings" round it. The so-called rings are a mighty swarm of meteorites—pieces of iron and stone of all sorts and sizes, which reflect the light of the sun to us. This ocean of matter is some miles deep, and stretches from a few thousand miles from the surface of the planet to 172,000 miles out in space. Some astronomers think that this is volcanic material which has been shot out of the planet. Others regard it as stuff which would have combined to form an eleventh moon but was prevented by the nearness of Saturn herself. There is certainly no life in Saturn.

FIG. 15.—THE PLANET MARS.

The two uppermost drawings are by Professor Lowell, July 8 and 12, 1907.

The lower drawing is by Professor Schiaparelli, May 1890. On each the polar caps and the famous canals are visible.

THE MOON

Mars and Venus are therefore the only planets, besides the earth, on which we may look for life; and in the case of Venus, the possibility is very faint. But what about the moons which attend the planets? They range in size from the little ten-miles-wide moons of Mars, to Titan, a moon of Saturn, and Ganymede, a satellite of Jupiter, which are about 3,000 miles in diameter. May there not be life on some of the larger of these moons? We will take our own moon as a type of the class.

A Dead World.

The moon is so very much nearer to us than any other heavenly body that we have a remarkable knowledge of it. In Fig. 16 you have a photograph, taken in one of our largest telescopes, of part of its surface. In a sense such a telescope brings the moon to within about fifty miles of us. We should see a city like London as a dark, sprawling blotch on the globe. We could just detect a Zeppelin or a *Diplodocus* as a moving speck against the surface. But we find none of these things. It is true that a few astronomers believe that they see signs of some sort of feeble life or movement on the moon. Professor Pickering thinks that he can trace some volcanic activity. He believes that there are areas of vegetation, probably of a low order, and that the soil of the moon may retain a certain amount of water in it. He speaks of a very thin atmosphere, and of occasional light falls of snow. He has succeeded in persuading some careful observers that there probably are slight changes of some kind taking place on the moon.

But there are many things that point to absence of air on the moon. Even the photographs we reproduce tell the same story. The edges of the shadows are all hard and black. If there had been an appreciable atmosphere it would have scattered the sun's light on to the

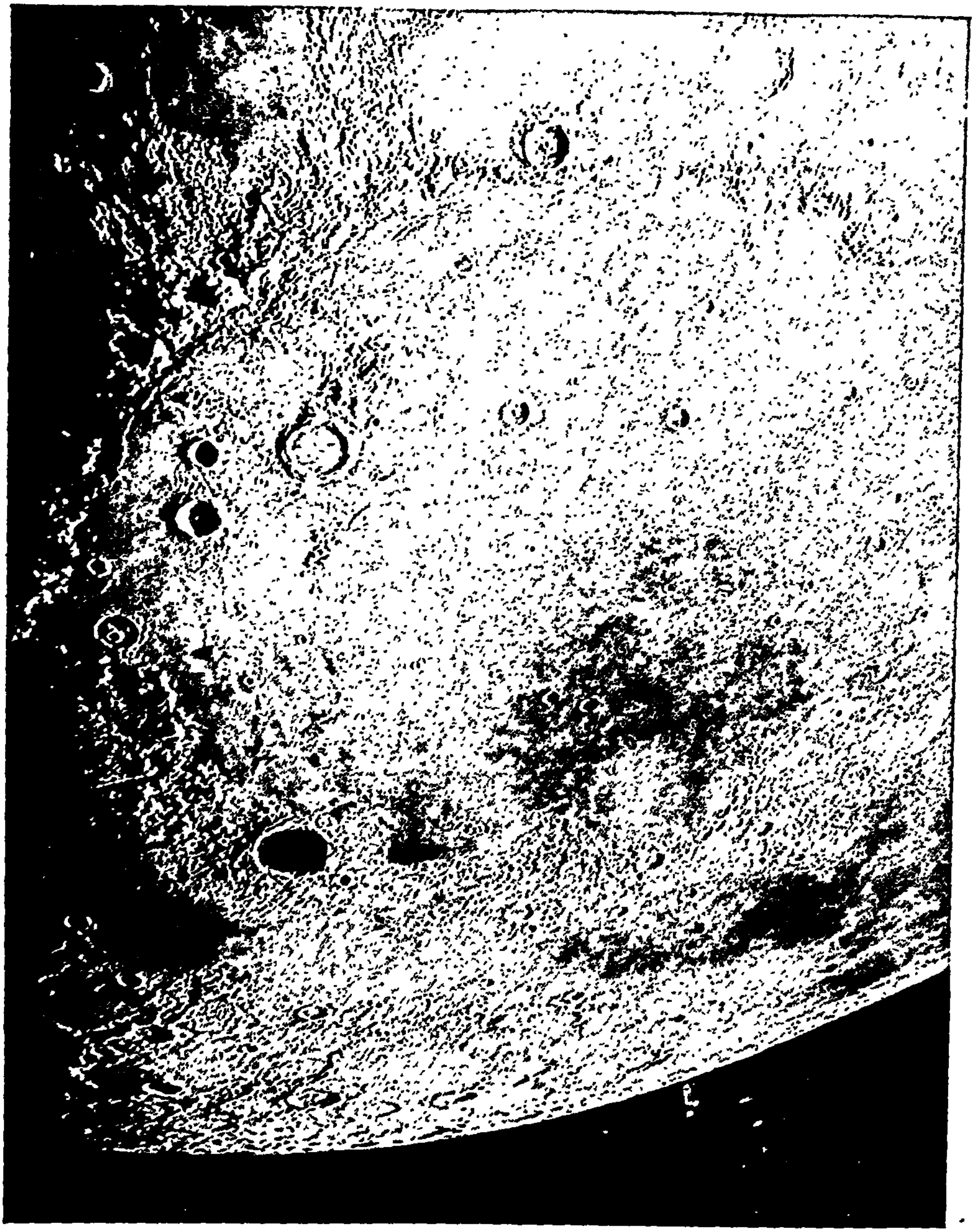


FIG. 16.—THE MOON.

Showing a great plain and some typical craters. There are thousands of these craters, and some theories of their origin are explained on the following page.

edges and produced a gradual shading off such as we see on the earth. This relative absence of air must give rise to some surprising effects. There will be no sounds on the moon, because sounds are merely air waves. Even a meteor shattering itself to a violent end against the surface of the moon would make no noise. Nor would it herald its coming by glowing into a "shooting star," as it would on entering the earth's atmosphere. There will be no floating dust, no scent, no twilight, no blue sky, no twinkling of the stars. The sky will be always black and the stars will be clearly visible by day as by night. The sun's wonderful corona, which no man on earth, even by seizing every opportunity during eclipses, can hope to see for more than two hours in all in a long lifetime, will be visible all day. So will the great red flames of the sun. Of course, there will be no life, and no landscape effects and scenery effects due to vegetation.

Photo: Observatoire, Paris.

FIG. 17.—THE MOON, SEPTEMBER 12, 1903.

Note the mysterious "rays" diverging from the central crater, and also the mountain peaks, with the dawn breaking on them, to the left of the photograph.

The moon takes approximately twenty-seven of our days to turn once on its axis. So for fourteen days there is continuous night, when the temperature must sink away down towards the absolute cold of space. This will be followed without an instant of twilight by full daylight. For another fourteen days the sun's rays will bear straight down, with no diffusion or absorption of their heat, or light, on the way. It does not follow, however, that the temperature of the moon's surface must rise enormously. It may not even rise to the temperature of melting ice. Seeing there is no air there can be no check on radiation. The heat that the moon gets will radiate away immediately. We know that amongst the coldest places on the earth are the tops of very high mountains, the points that have reared themselves nearest to the sun but farthest out of the sheltering blanket of the earth's atmosphere. The actual temperature of the moon's surface by day is a moot point. It may be below the freezing-point or above the boiling-point of water.

The Mountains of the Moon.

The lack of air is considered by many astronomers to furnish the explanation of the enormous number of "craters" which pit the moon's surface. There are about a hundred thousand of these strange rings, and it is now believed by many that they are spots where very large meteorites, or even planetoids, splashed into the moon when its surface was still soft. Other astronomers think that they are the remains of gigantic bubbles which were raised in the moon's "skin," when the globe was still molten, by volcanic gases from below. A few astronomers think that they are, as is popularly supposed, the craters of extinct volcanoes. Our craters, on the earth, are generally deep cups, whereas these ring-formations on the moon are more like very shallow and broad saucers. Clavius, the largest of them, is 123 miles across the interior, yet its encircling rampart is not a mile high.

The mountains on the moon (Fig. 17) rise to a great height, and are extraordinarily gaunt and rugged. They are like fountains of lava, rising in places to 26,000 and 27,000 feet. The lunar Apennines have three thousand steep and weird peaks. Our terrestrial mountains are continually worn down by frost acting on

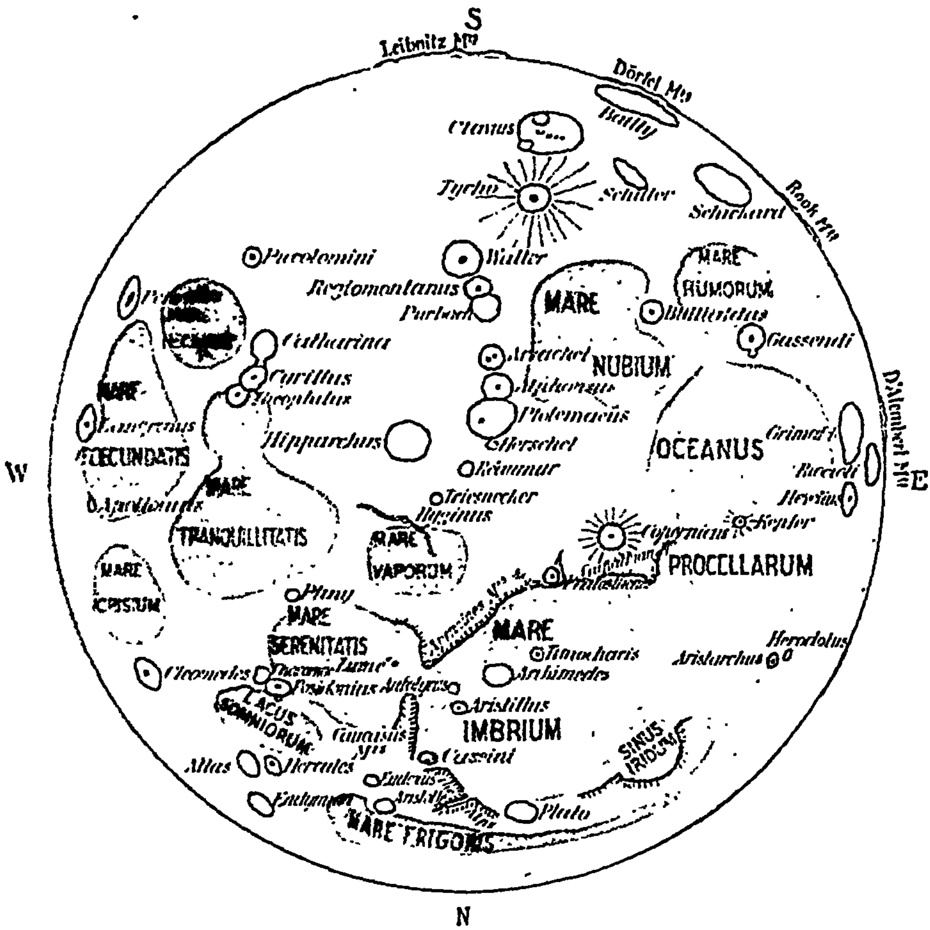


FIG. 18.—A MAP OF THE CHIEF PLAINS AND CRATERS OF THE MOON

The plains were originally supposed to be seas: hence the name "Mare."

moisture and by ice and water, but there are none of these agencies operating on the moon. Its mountains are comparatively "everlasting hills."

The moon is interesting to us precisely because it is a dead world. It seems to show how the earth, or any cooling metal globe, will evolve in the remote future. We do not know if there was ever life on the moon, but in any case it cannot have proceeded far in development. At the most we can imagine some strange lowly forms of vegetation lingering here and there in pools of heavy gas, expanding during the blaze of the sun's long day, and frozen rigid during the long night.

METEORS AND COMETS

We may conclude our survey of the solar system with a word about "shooting stars," or meteors, and comets. There are few now who do not know that the streak of fire which suddenly lights the sky overhead at night means that a piece of stone or iron has entered our atmosphere from outer space, and has been burned up by friction. It was travelling at, perhaps, twenty or thirty miles a second. At seventy or eighty miles above our heads it began to glow, as at that height the air is thick enough to offer serious friction and raise it to a white

heat. By the time the meteor reached about twenty miles or so from the earth's surface it was entirely dissipated, as a rule in fiery vapour.

Millions of Meteorites.

It is estimated that between ten and a hundred million meteorites enter our atmosphere and are cremated, every day. Most of them weigh only an ounce or two, and are invisible. Some of them weigh a ton or more, but even against these large masses the air acts as a kind of "torpedo-net." They generally burst into fragments and fall without doing damage.

It is clear that "empty space" is, at least within the limits of our solar system, full of these things. They swarm like fishes in the seas. Like the fishes, moreover, they may be either solitary or gregarious. The solitary bit of cosmic rubbish is the meteorite, which we have just examined. A "social" group of meteorites is the essential part of a comet. The nucleus, or bright central part, of the head of a comet (Fig. 20) consists of a swarm, sometimes thousands of miles wide, of these pieces of iron or stone. This swarm has come under the sun's gravitational influence, and is forced to travel round it. From some dark region of space it has moved slowly into our system. It is not then a comet, for it has no tail. But as the

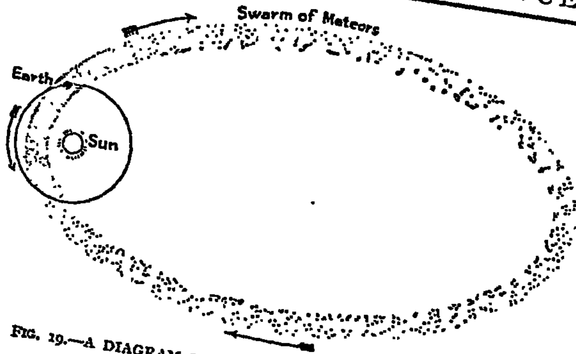


FIG. 19.—A DIAGRAM OF A STREAM OF METEORS SHOWING THE EARTH PASSING THROUGH THEM.

Photo: Royal Observatory, Greenwich.

FIG. 20.—COMET, SEPTEMBER 29, 1908.

Notice the tendency to form a number of tails. (See photograph on next page.)

crowded meteors approach the sun, and the speed increases, mutual friction raises at least a large part of them to a white heat. They give off fine vapour-like matter and the fierce flood of light from the sun sweeps this vapour out in an ever-lengthening tail. Whatever way the comet is travelling, the tail always points away from the sun.

A Great Comet.

The vapoury tail often grows to an enormous length as the comet approaches the sun. The great comet of 1843 had a tail two hundred million miles long. It is, however, composed of the thinnest vapours imaginable. Twice during the nineteenth century the earth passed through the tail of a comet, and nothing was felt. The vapours of the tail are, in fact, so attenuated that we can hardly imagine them to be white-hot. They may be lit by some electrical force. However that may be, the comet dashes round the sun, often at three or four hundred miles a second, then may pass gradually out of our system once more. It may be a thousand years, or it may be fifty years, before the monarch of the system will summon it again to make its fiery journey round his throne.

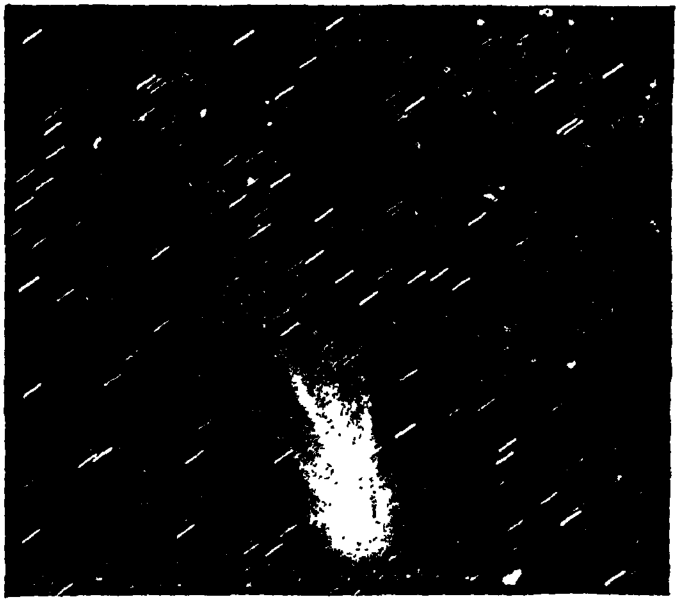


Photo: Royal Observatory, Greenwich.

FIG. 21.—COMET, OCTOBER 3, 1908.

The process has gone further and a number of distinct tails can now be counted.

THE STELLAR UNIVERSE

§ 1

The immensity of the Stellar Universe, as we have seen, is beyond our apprehension. The sun is nothing more than a very ordinary star, perhaps an insignificant one. There are stars enormously greater than the sun. One such, Betelgeux, has recently been measured, and its diameter is more than 300 times that of the sun.

The proof of the similarity between our sun and the stars has come to us through the spectroscope. The elements that we find by its means in the sun are also found in the same way in the stars. Matter, says the spectroscope, is essentially the same everywhere, in the earth and the sun, in the comet that visits us once in a thousand years, in the star whose distance is incalculable, and in the great clouds of "fire-mist" that we call nebulæ.

The Evolution of Stars.

In considering the evolution of the stars let us keep two points clearly in mind. The starting-point, the nebula, is no figment of the scientific imagination. Hundreds of thousands of nebulæ, besides even vaster irregular stretches of nebulous matter, exist in the heavens. But the stages of the evolution of this stuff into stars are very largely a matter of speculation. Possibly there is more than one line of evolution, and the various theories may be reconciled. And this applies also to the theories of the various stages through which the stars themselves pass on their way to extinction.

The light of about a quarter of a million stars has been analysed in the spectroscope, and it is found that they fall into about a dozen classes

which generally correspond to stages in their evolution (Fig. 22).

The Age of Stars.

In its main lines the spectrum of a star corresponds to its colour, and we may roughly group the stars into red, yellow, and white. This is also the order of increasing temperature, the red stars being the coolest and the white stars the hottest. We might therefore imagine that the white stars are the youngest, and that as they grow older and cooler they become yellowish, then red, and finally become invisible—just as a cooling white-hot iron would do. But a very interesting recent research shows that there are two kinds of red stars; some of them are amongst the oldest stars and some are amongst the youngest. The facts appear to be that when a star is first formed it is not very hot. It is an immense mass of diffuse gas glowing with a dull-red heat. It contracts under the mutual gravitation of its particles, and as it does so it grows hotter. It acquires a yellowish tinge. As it continues to contract it grows hotter and hotter until its temperature reaches a maximum as a white star. At this point the contraction process does not stop, but the heating process does. Further contraction is now accompanied by cooling, and the star goes through its colour changes again, but this time in the inverse order. It contracts and cools to yellow and finally to red. But when it again becomes a red star it is enormously denser and smaller than when it began as a red star. Consequently the red stars are divided into two classes called, appropriately, Giants and Dwarfs. This theory, which we owe to an American astronomer, H. N. Russell, has been successful in explaining a variety of phenomena, and there is consequently good reason to suppose it to be true. But the question as to how the red giant stars were formed has received less satisfactory and precise answers.

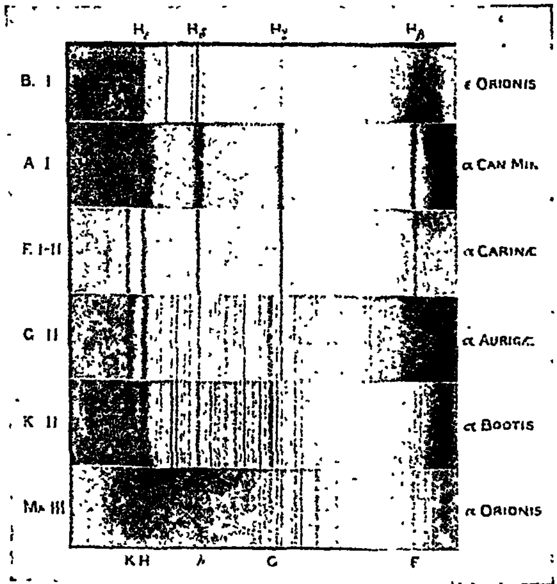


Photo: Harvard College Observatory.

FIG. 22.—TYPICAL SPECTRA.

Six main types of stellar spectra. Notice the lines they have in common, showing what elements are met with in different types of stars. Each of these spectra corresponds to a different set of physical and chemical conditions.

The most commonly accepted theory is the nebular theory.

The nebular theory is dealt with in a later chapter.

THE SPECTROSCOPE (see page 11) IS AN INSTRUMENT FOR ANALYSING LIGHT; IT PROVIDES THE MEANS FOR IDENTIFYING DIFFERENT SUBSTANCES.

This pictorial diagram illustrates the principle of Spectrum Analysis, showing how sunlight is decomposed into its primary colours. What we call white light is composed of seven different colours. The diagram is relieved of all detail which would unduly obscure the simple process by which a ray of light is broken up by a prism into different wave-lengths. The spectrum rays have been greatly magnified.

II

THE STORY OF EVOLUTION

INTRODUCTORY

THE BEGINNING OF THE EARTH—MAKING A HOME FOR LIFE—THE FIRST LIVING CREATURES

§ 1

THE Evolution-idea is a master-key that opens many doors. It is a luminous interpretation of the world, throwing the light of the past upon the present. Everything is seen to be an antiquity, with a history behind it—a *natural history*, which enables us to understand in some measure how it has come to be as it is. We cannot say more than "understand in some measure," for while the *fact* of evolution is certain, we are only beginning to discern the *factors* that have been at work.

The evolution-idea is very old, going back to some of the Greek philosophers, but it is only in modern times that it has become an essential part of our mental equipment. It is now an everyday intellectual tool. It was applied to the origin of the solar system and to the making of the earth before it was applied to plants and animals; it was extended *from* these to man himself; it spread to language, to folk-ways, to institutions. Within recent years the evolution-idea has been applied to the chemical elements, for it appears that uranium may change into radium, that radium may produce helium, and that lead is the final stable result when the changes of uranium are complete. Perhaps all the elements may be the outcome of an inorganic evolution. Not less important is the extension of the evolution-idea to the world within as well as to the world without. For alongside of the evolution of bodies and brains is the evolution of feelings and emotions, ideas and imagination.

Photo: Rischgitz Collection.

CHARLES DARWIN.

Greatest of naturalists, who made the idea of evolution current intellectual coin, and in his *Origin of Species* (1859) made the whole world new.

Organic evolution means that the present is the child of the past and the parent of the future. It is not a power or a principle; it is a process—a process of becoming. It means that the present-day animals and plants and all the subtle inter-relations between them have arisen in a natural knowable way from a preceding state of affairs on the whole somewhat simpler, and that again from forms and inter-relations simpler still, and so on backwards and backwards for millions of years till we lose all clues in the thick mist that hangs over life's beginnings.

Our solar system was once represented by a nebula of some sort, and we may speak of the evolution of the sun and the planets. But since it has been *the same material throughout* that

has changed in its distribution and forms, it might be clearer to use some word like genesis. Similarly, our human institutions were once very different from what they are now, and we may speak of the evolution of government or of cities. But Man works with a purpose, with ideas and ideals in some measure controlling his actions and guiding his achievements, so that it is probably clearer to keep the good old word history for all processes of social becoming in which man has been a conscious agent. Now between the genesis of the solar system and the history of civilisation there comes the vast process of organic evolution. The word development should be kept for the becoming of the individual, the chick out of the egg, for instance.

Organic evolution is a continuous natural process of racial change, by successive steps in a definite direction, whereby distinctively new individualities arise, take root, and flourish, sometimes alongside of, and sometimes, sooner or later, in place of, the originative stock. Our domesticated breeds of pigeons and poultry are the results of evolutionary change whose origins are still with us in the Rock Dove and the Jungle Fowl; but in most cases in Wild Nature the ancestral stocks of present-day forms are long since extinct, and in many cases they are unknown. Evolution is a long process of coming and going, appearing and disappearing, a long-drawn-out sublime process like a great piece of music.

Photo: Lick Observatory.

A GIANT SPIRAL NEBULA.

Laplace's famous theory was that the planets and the earth were formed from great whirling nebulæ (see page 27).

§ 2

When we speak the language of science we cannot say "In the beginning," for we do not know of and cannot think of any condition of things that did not arise from something that went before. But we may qualify the phrase, and legitimately inquire into the beginning of the earth within the solar system. If the result of this inquiry is to trace the sun and the planets back to a nebula we reach only a relative beginning. The nebula has to be accounted for. And even before matter there may have been a pre-material world. If we say, as was said long ago, "In the beginning was Mind," we may be expressing or trying to express a

The Beginning of the Earth.

great truth, but we have gone BEYOND SCIENCE.

One of the grandest pictures that the scientific mind has ever thrown upon the screen is that of the Nebular Hypothesis. According to Laplace's famous form of this theory (1796), the solar system was once a gigantic glowing mass, spinning slowly and uniformly around its centre. As the incandescent world-cloud of gas cooled, and its speed of rotation increased, the shrinking mass gave off a separate whirling ring, which broke up and gathered together again as the first and most distant planet. The main mass gave off another ring and another till all the planets, including the earth, were formed. The central mass persisted as the sun.

The Nebular Hypothesis.

Laplace spoke of his theory, which Kant had anticipated forty-one years before, with scientific caution: "*conjectures which I present with* all the distrust which everything not the result of observation or of calculation ought to inspire." Subsequent research justified his distrust, for it has been shown that the original nebula need not have been hot and need not have been gaseous. Moreover, there are great difficulties in Laplace's theory of the separation of successive rings from the main mass, and of the condensation of a whirling gaseous ring into a planet.

So it has come about that the picture of a hot gaseous nebula revolving as a unit body has given place to other pictures. Thus Sir Norman Lockyer pointed out (1890) that the earth is gathering to itself millions of meteorites every day; this has been going on for millions of years; in distant ages the accretion may have been vastly more rapid and voluminous; and so the earth has grown! Now the meteoritic contributions are undoubted, but they require a centre to attract them, and the difficulty is to account for the beginning of a collecting centre or planetary nucleus. Moreover, meteorites are sporadic and erratic, scattered hither and thither rather than collecting into unit-bodies. As Professor Chamberlin says, "meteorites have rather the characteristics of the wreckage of some earlier organisation than of the parentage of our planetary system." Several other theories have been propounded to account for the origin of the earth, but the one that has found most favour in the eyes of authorities is that of Chamberlin and Moulton. According to this theory a great nebular mass condensed to form the sun, from which under the attraction of passing stars planet after planet, the earth included, was heaved off in the form of knotted spiral nebulæ, like many of those now observed in the heavens.

Of great importance were the "knots," for they served as collecting centres drawing flying matter into their clutches. Whatever part of the primitive bolt escaped and scattered was drawn out into independent orbits round the sun, forming the "planetesimals" which behave like minute planets. These planetesimals formed the food on which the knots subsequently fed.

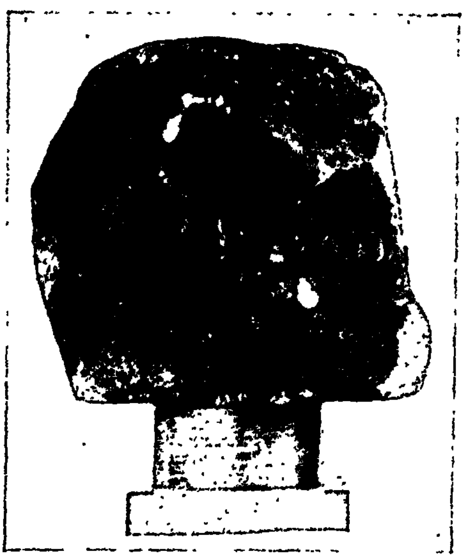


Photo: Natural History Museum.

METEORITE WHICH FELL NEAR SCARBOROUGH, AND IS NOW TO BE SEEN IN THE NATURAL HISTORY MUSEUM.

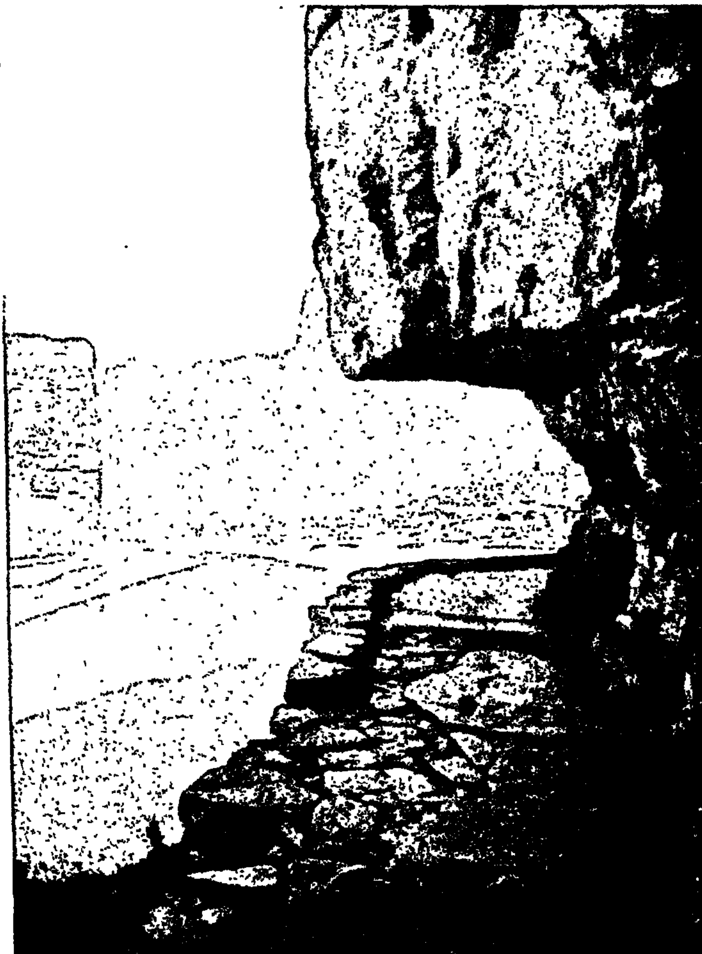
It weighs about 56 lb., and is a "stony" meteorite, i.e. an aerolite.

The Growth of the Earth.

It has been calculated that the newborn earth—the "earth-knot" of Chamberlin's theory—had a diameter of about 5,500 miles. But it grew by drawing planetesimals into itself until it had a diameter of over 8,100 miles at the end of its growing period. Since then it has shrunk, by periodic shrinkages which have meant the buckling up of successive series of mountains,

and it has now a diameter of 7,918 miles. But during the shrinking the earth became more varied.

A sort of slow boiling of the internally hot earth often forced molten matter through the cold outer crust, and there came about a gradual assortment of lighter materials nearer the surface and heavier materials deeper down. The continents are built of the lighter materials, such as granites, while the beds of the great oceans are made of the heavier materials such as basalts. In limited areas land has often become sea, and sea has often given place to land, but the probability is that the distinction of the areas corresponding to the great continents and oceans goes back to a very early stage.



Reproduced from the Smithsonian Report, 1915.

A LIMESTONE CANYON.

Many fossils of extinct animals have been found in such rock formations.

The lithosphere is the more or less stable crust of the earth, which may have been, to begin with, about 50 miles in thickness. It seems that the young earth had no atmosphere, and that ages passed before water began to accumulate on its surface—before, in other words, there was any hydrosphere. The water came from the earth itself, to begin with, and it was long before there was any rain dissolving out saline matter from the exposed rocks and making the sea salt. The weathering of the high grounds of the ancient crust by air and water furnished the material which formed the sandstones and mudstones and other sedimentary rocks, which are said to amount to a thickness of over fifty miles in all.

§ 3

Making a Home for Life.

It is interesting to inquire how the callous, rough-and-tumble conditions of the outer world in early days were replaced by others that allowed of the germinaton and growth of that tender plant we call LIFE. There are very tough living creatures, but the average organism is ill suited for violence. Most living creatures are adapted to mild temperatures and gentle reactions.

Hence the fundamental importance of the early atmosphere, heavy with planetesimal dust, in blanketing the earth against intensities of radiance from without, as Chamberlin says, and inequalities of radiance from within. This was the first preparation for life, but it was an atmosphere without free oxygen. Not less important was the appearance of pools and lakelets, of lakes and seas. Perhaps the early waters covered the earth. And water was the second preparation for life—water, that can dissolve a larger variety of substances in greater concentration than any other liquid; water, that in summer does not readily evaporate altogether from a pond, nor in winter freeze throughout its whole extent; water, that is such a mobile vehicle and such a subtle cleaver of substances; water, that forms over 80 per cent. of living matter itself.

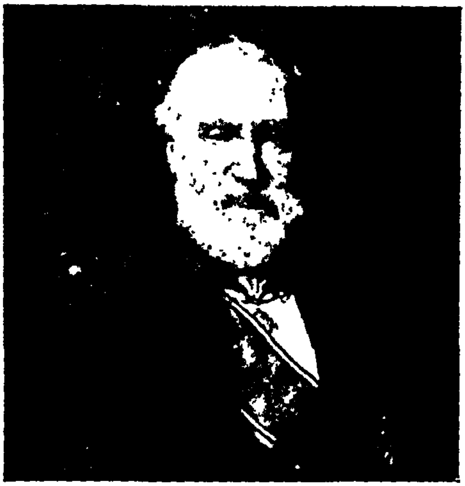


Photo: Rischgitz Collection.

LORD KELVIN.

One of the greatest physicists of the nineteenth century. He estimated the age of the earth at 20,000,000 years. He had not at his disposal, however, the knowledge of recent discoveries, which have resulted in this estimate being very greatly increased.

Of great significance was the abundance of carbon, hydrogen, and oxygen (in the form of carbonic acid and water) in the atmosphere of the cooling earth, for these three wonderful elements have a unique *ensemble* of properties—ready to enter into reactions and relations, making great diversity and complexity possible, favouring the formation of the plastic and permeable materials that build up living creatures. We must not pursue the idea, but it is clear that the stones and mortar of the inanimate world are such that they built a friendly home for life.

Origin of Living Creatures upon the Earth.

During the early chapters of the earth's history, no living creature that we can imagine could possibly have lived there. The temperature was too high; there was neither atmosphere nor surface water. Therefore it follows that at some uncertain, but inconceivably distant date, living creatures appeared upon the earth. No one knows how, but it is interesting to consider possibilities.

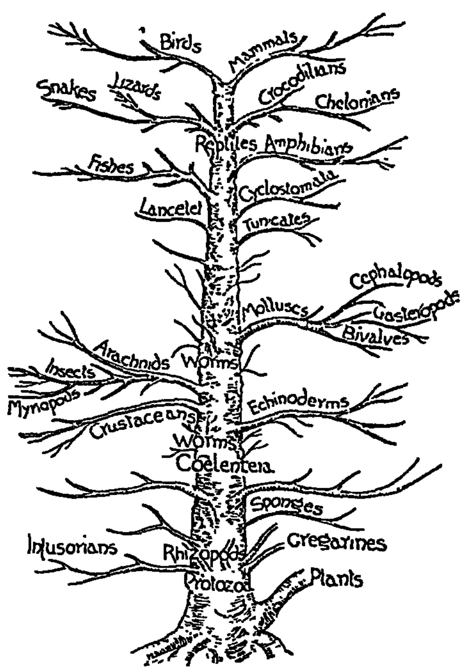
From ancient times it has been a favourite answer that the dust of the earth may have become living in a way which is outside scientific description. This answer forecloses the question, and it is far too soon to do that. Science must often say "Ignoramus": Science should be slow to say "Ignorabimus."

A second position held by Helmholtz, Lord Kelvin, and others, suggests that minute living creatures may have come to the earth from elsewhere, in the cracks of a meteorite or among cosmic dust. It must be remembered that seeds can survive prolonged exposure to very low temperatures; that spores of Bacteria can survive high temperature; that seeds of plants and germs of animals in a state of "latent life" can survive prolonged drought and absence of oxygen. It is possible, according to Berthelot, that as long as there is not molecular disintegration vital activities may be suspended for a time, and may afterwards recommence when appropriate conditions are restored. Therefore, one should be slow to say that a long journey through space is impossible. The obvious limitation of Lord Kelvin's theory is that it only shifts the problem of the origin of organisms (i.e. living creatures) from the earth to elsewhere.

The third answer is that living creatures of a very simple sort may have emerged on the earth's surface from not-living material, e.g. from some semi-fluid carbon compounds activated by ferments. The tenability of this view is suggested by the achievements of the synthetic chemists, who are able artificially to build up substances such as oxalic acid, indigo, salicylic

acid, caffeine, and grape-sugar. We do not know, indeed, what in Nature's laboratory would take the place of the clever synthetic chemist, but there seems to be a tendency to complexity. Corpuscles form atoms, atoms form molecules, small molecules large ones.

Various concrete suggestions have been made in regard to the possible origin of living matter, which will be dealt with in a later chapter. So far as we know of what goes on to-day, there is no evidence of spontaneous generation; organisms seem always to arise from pre-existing organisms of the same kind; where any suggestion of the contrary has been fancied, there have been flaws in the experimenting. But it is one thing to accept the verdict "omne vivum e vivo" as a fact to which experiment has not yet discovered an exception, and another thing to maintain that this must always have been true or must always remain true.



GENEALOGICAL TREE OF ANIMALS.

Showing in order of evolution the general relations of the chief classes into which the world of living things is divided. This scheme represents the present stage of our knowledge, but is admittedly provisional.

If the synthetic chemists should go on surpassing themselves, if substances like white of egg should be made artificially, and if we should get more light on possible steps by which simple living creatures may have arisen from not-living materials, this would not greatly affect our general outlook on life, though it would increase our appreciation of what is often libelled as "inert" matter. If the dust of the earth did naturally give rise very long ago to living creatures, if they are in a real sense born of her and of the sunshine, then the whole world becomes more continuous and more vital, and all the inorganic groaning and travailing becomes more intelligible.

§ 4

The first Organisms upon the Earth.

We cannot have more than a speculative picture of the first living creatures upon the earth or, rather, in the waters that covered the earth. A basis for speculation is to be found, however, in the simplest creatures living to-day, such as some of the Bacteria and one-celled animalcules, especially those called *Protists*, which have not taken any very definite step towards becoming either plants or animals. No one can be sure, but there is much to be said for the theory that the first creatures were microscopic globules of living matter, not unlike the simplest Bacteria of to-day, but able to live on air, water, and dissolved salts. From such a source may have originated a race of one-celled marine organisms which were able to manufacture chlorophyll, or something like chlorophyll, that is to say, the green pigment which makes it possible for plants to utilise the energy of the sunlight in breaking up carbon dioxide and in building up (photosynthesis) carbon compounds like sugars and starch. These little units were probably encased in a cell-wall of cellulose, but their boxed-in energy expressed itself in the undulatory movement of a lash or flagellum, by means of which they propelled themselves energetically through the water. There are many similar organisms to-day, mostly in water, but some of them—simple one-celled plants—paint the tree-stems and even the paving-stones green in wet weather.

According to Prof. A. H. Church there was a long chapter in the history of the earth when the sea that covered everything teemed with these green flagellates—the originators of the Vegetable Kingdom.

On another tack, however, there probably evolved a series of simple predatory creatures, not able to build up organic matter from air, water, and salts, but devouring their neighbours. These units were not closed in with cellulose, but remained naked, with their living matter or protoplasm flowing out in changeful processes, such as we see in the Amœbæ in the ditch or in our own white blood corpuscles and other amœboid cells. These were the originators of the animal kingdom. Thus from very simple Protists the first animals and the first plants may have arisen. All were still very minute, and it is worth remembering that had there been any scientific spectator after our kind upon the earth during these long ages, he would have lamented the entire absence of life, although the seas were teeming. The simplest forms of life and the protoplasm which Huxley called the physical basis of life will be dealt with in the chapter on Biology in a later section of this work.

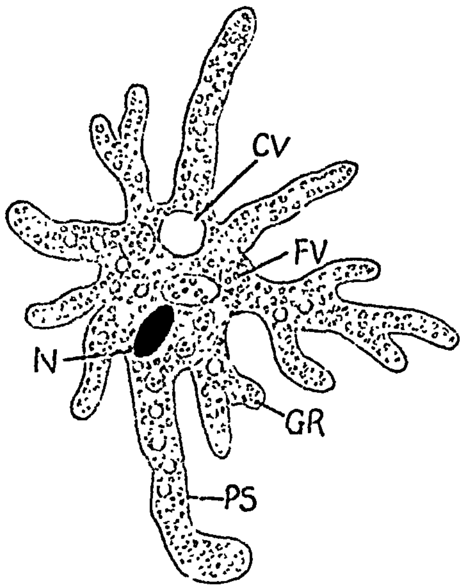


DIAGRAM OF AMŒBA.
(Greatly magnified.)

The amœba is one of the simplest of all animals, and gives us a hint of the original ancestors. It looks like a tiny irregular speck of greyish jelly, about 1/100th of an inch in diameter. It is commonly found gliding on the mud or weeds in ponds, where it engulfs its microscopic food by means of outflowing lobes (PS). The food vacuole (FV) contains ingested food. From the contractile vacuole (CV) the waste matter is discharged. N is the nucleus, GR, granules.

FIRST GREAT STEPS IN EVOLUTION

THE FIRST PLANTS—THE FIRST ANIMALS—BEGINNINGS OF BODIES—EVOLUTION OF SEX—BEGINNING OF NATURAL DEATH

§ 1

However it may have come about, there is no doubt at all that one of the first great steps in Organic Evolution was the forking of the genealogical tree into Plants and Animals—the most important parting of the ways in the whole history of Nature.

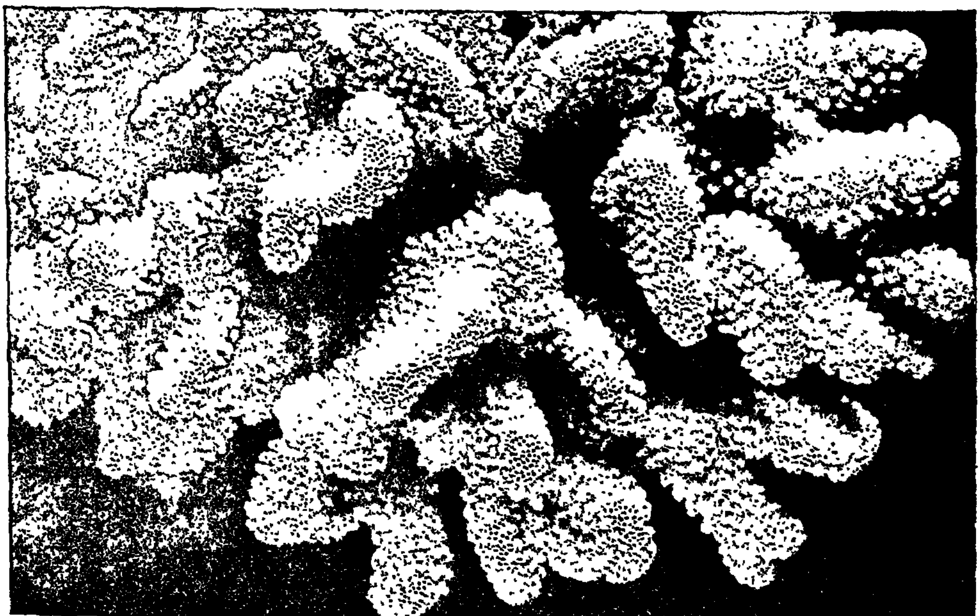
The Contrast between Plants and Animals.

Typical plants have chlorophyll; they are able to feed at a low chemical level on air, water, and salts, using the energy of the sunlight in their photosynthesis. They have their cells boxed in by cellulose walls, so that their opportunities for motility are greatly restricted. They manufacture much more nutritive material than they need, and live far below their income. They have no ready way of getting rid of any nitrogenous waste matter that they may form, and this probably helps to keep them sluggish.

Animals, on the other hand, feed at a high chemical level, on the carbohydrates (e.g. starch and sugar), fats, and proteins (e.g. gluten, albumin, casein) which are manufactured by other animals, or to begin with, by plants. Their cells have not cellulose walls, nor in most cases much wall of any kind, and motility in the majority is unrestricted. Animals live much more nearly up to their income. If we could make for an animal and a plant of equal weight two fractions showing the ratio of the upbuilding, constructive, chemical processes to the down-breaking, disruptive, chemical processes that go on in their respective bodies, the ratio for the plant would be much greater than

the corresponding ratio for the animal. In other words, animals take the munitions which plants laboriously manufacture and explode them in locomotion and work; and the entire system of animate nature depends upon the photosynthesis that goes on in green plants.

As the result of much more explosive life, animals have to deal with much in the way of nitrogenous waste products, the ashes of the living fire, but these are usually got rid of very effectively, e.g. in the kidney filters, and do not clog the system by being deposited as crystals and the like, as happens in plants. Sluggish animals like sea-squirts which have no kidneys are exceptions that prove the rule, and it need hardly be said that the statements that have been made in regard to the contrasts between plants and animals are general statements. There is often a good deal of the plant about the animal, as in sedentary sponges, zoophytes, corals, and sea-squirts, and there is often a little of the animal about the plant, as we see in the movements of all shoots and roots and leaves, and occasionally in the parts of the flower. But the important fact is that on the early forking of the genealogical tree, i.e. the divergence of plants and animals, there depended and depends all the higher life of the animal kingdom, not to speak of mankind. The continuance of civilisation, the upkeep of the human and animal population of the globe, and even the supply of oxygen to the air we breathe, depend on the silent laboratories of the green leaves, which are able with the help of the sunlight to use carbonic acid, water, and salts to build up the bread of life.



From the Smithsonian Report, 1917.

A PIECE OF A REEF-BUILDING CORAL, BUILT UP BY A LARGE COLONY OF SMALL SEA-ANEMONE-LIKE POLYPS, EACH OF WHICH FORMS FROM THE SALTS OF THE SEA A SKELETON OR SHELL OF LIME.

The wonderful mass of corals, which are very beautiful, are the skeleton remains of hundreds of these little creatures.

§ 2

The Beginnings of Land Plants.

It is highly probable that for long ages the waters covered the earth, and that all the primeval vegetation consisted of simple Flagellates in the universal Open Sea. But contraction of the earth's crust brought about elevations and depressions of the sea-floor, and in places the solid substratum was brought near enough the surface to allow the floating plants to begin to settle down without getting out of the light.

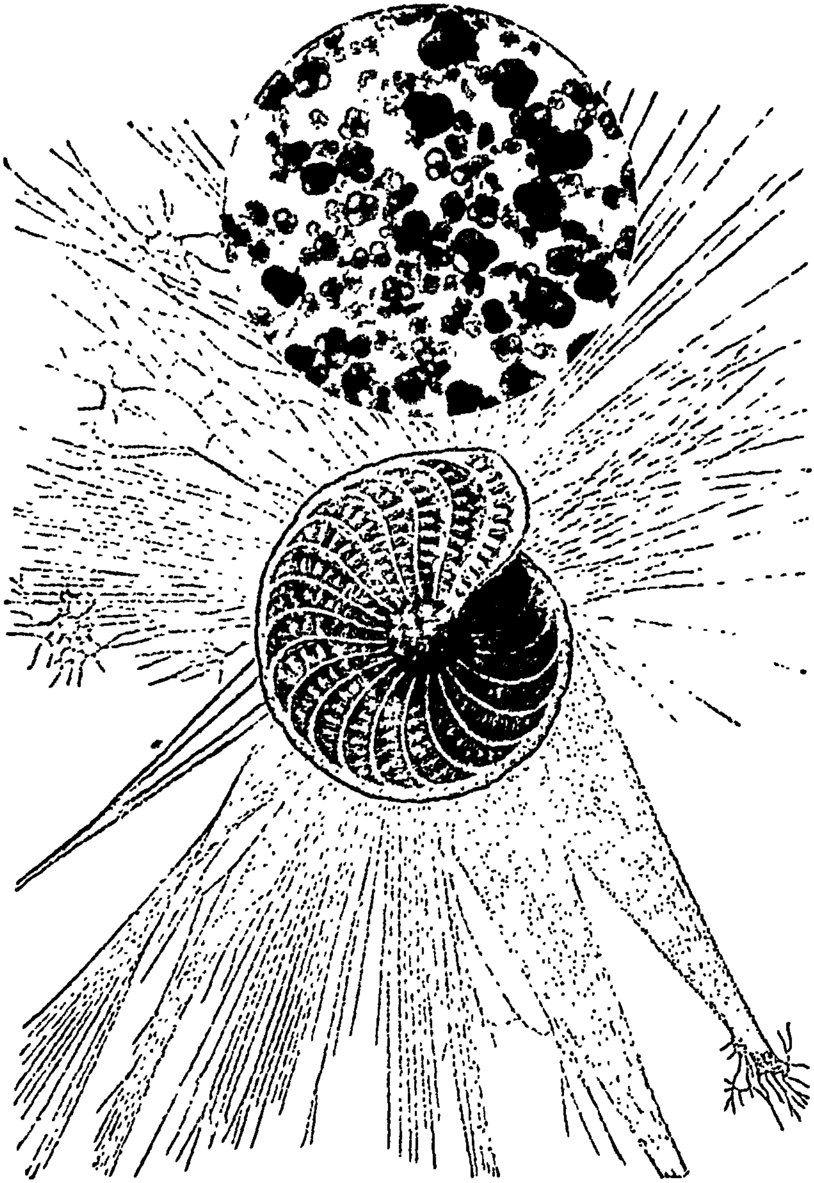


Photo: J. J. Ward, F.E.S.

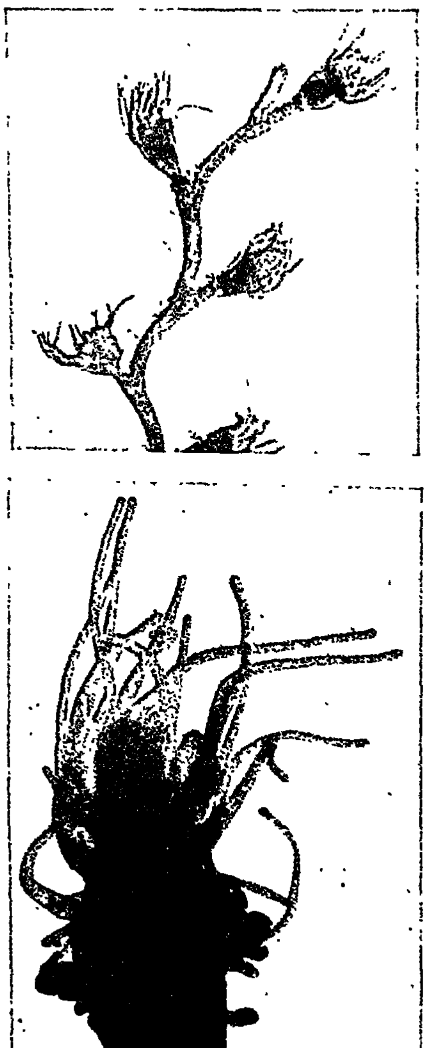
THE INSET CIRCLE SHOWS A GROUP OF CHALK-FORMING ANIMALS, OR FORAMINIFERA, EACH ABOUT THE SIZE OF A VERY SMALL PIN'S HEAD.

They form a great part of the chalk cliffs of Dover and similar deposits which have been raised from the floor of an ancient sea.

THE ENORMOUSLY ENLARGED ILLUSTRATION IS THAT OF A COMMON FORAMINIFER (POLYSTOMELLA) SHOWING THE SHELL IN THE CENTRE AND THE OUTFLOWING NETWORK OF LIVING MATTER, ALONG WHICH GRANULES ARE CONTINUALLY TRAVELLING, AND BY WHICH FOOD PARTICLES ARE ENTANGLED AND DRAWN IN.

Reproduced by permission of the Natural History Museum (after Max Schultze).

This is how Professor Church pictures the beginning of a fixed vegetation—a very momentous step in evolution. It was perhaps among this



Photos: J. J. Ward, F.E.S.

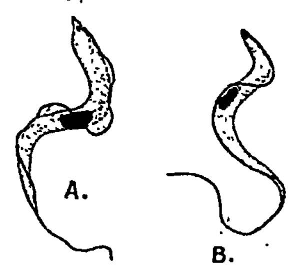
A PLANT-LIKE ANIMAL, OR ZOOPHYTE, CALLED OBELIA.

Consisting of a colony of small polyps, whose stinging tentacles are well shown greatly enlarged in the lower photograph.

early vegetation that animals had their first successes. As the floor of the sea in these shallow areas was raised higher and higher there was a beginning of dry land. The sedentary plants already spoken of were the ancestors of the shore seaweeds, and there is no doubt that when we go down at the lowest tide and wade cautiously out among the jungle of vegetation only exposed on such occasions we are getting a glimpse of very ancient days. *This* is the forest primeval.

The Protozoa.

Animals below the level of zoophytes and sponges are called Protozoa. The word obviously means "First Animals," but all that we can say is that the very simplest of them may give us some hint of the simplicity of the original first animals. For it is quite certain that the vast majority of the Protozoa to-day are far too complicated to be thought of as primitive. Though most of them are microscopic, each is an animal complete in itself, with the same fundamental bodily attributes as are manifested in ourselves. They differ from animals of higher degree in not being built up of the unit areas or corpuscles called cells. They have no cells, no tissues, no organs, in the ordinary acceptation of these words, but many of them show a great complexity of internal structure, far exceeding that of the ordinary cells that build up the tissues of higher animals. They are complete living creatures which have not gone in for body-making.



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TRYPANOSOMA GAMBIENSE.

(Very highly magnified.)

The microscopic animal Trypanosome, which causes Sleeping Sickness. The study of these organisms has of late years acquired an immense importance on account of the widespread and dangerous maladies to which some of them give rise. It lives in the blood of man, who is infected by the bite of a Tse-tse fly which carries the parasite from some other host.

In the dim and distant past there was a time when the only animals were of the nature of Protozoa, and it is safe to say that one of the great steps in evolution was the establishment of three great types of Protozoa: (*a*) Some were very active, the Infusorians, like the slipper animalcule, the night-light (Noctiluca), which makes the seas phosphorescent at night, and the deadly Trypanosome, which causes

food-canal. If a portion of the living matter of these Protozoa should gather round each of the nuclei, then *that would be the beginning of a body.* It would be still nearer the beginning of a body if division of labour set in, and if there was a setting apart of egg-cells and sperm-cells distinct from body-cells.

Photo: J. J. Ward, F.E.S.

GREEN HYDRA.

A little freshwater polyp, about half an inch long, with a crown of tentacles round the mouth. It is seen giving off a bud, a clear illustration of asexual reproduction. When a tentacle touches some small organism the latter is paralysed and drawn into the mouth.

It was possibly in some such way that animals and plants with a body were first evolved. Two points should be noticed, that body-making is not essentially a matter of size, though it made large size possible. For the body of a many-celled Wheel Animalcule or Rotifer is no bigger than many a Protozoon. Yet the Rotifer—we are thinking of Hydatina—has nine hundred odd cells, whereas the Protozoon has only one, except in forms like Volvox. Secondly, it is a luminous fact that *every many-celled animal from sponge to man that multiplies in the ordinary way begins at the beginning again as a "single cell,"* the fertilised egg-cell. It is, of course, not an ordinary single cell that develops into an earthworm or a butterfly, an eagle, or a man; it is a cell in which a rich inheritance, the fruition of ages, is somehow condensed; but it is interesting to bear in mind the elementary fact that every many-celled creature, reproduced in the ordinary way and not by budding or the like, starts as a fertilised egg-cell. The coherence of the daughter-cells into which the fertilised egg-cell divides is a reminiscence, as it were, of the primeval coherence of daughter-units that made the first body possible.

The Beginning of Sexual Reproduction.

A freshwater Hydra, growing on the duckweed, usually multiplies by budding. It forms daughter-buds, living images of itself; a check comes to nutrition and these daughter-buds go free. A big sea-anemone may divide in two or more parts, which become separate animals. This is asexual reproduction, which means that the multiplication takes place by dividing into two or many portions, and not by liberating egg-cells and sperm-cells. Among animals as among plants, asexual reproduction is very common. But it has great disadvantages, for it is apt to be physiologically expensive, and it is beset with difficulties when the body shows great division of labour, and is very intimately bound into unity. Thus, no one can think of a bee or a bird multiplying by division or by budding. Moreover, if the body of the parent has suffered from injury or deterioration, the result of this is bound to be handed on to the next generation if asexual reproduction is the only method.

Splitting into two or many parts was the old-fashioned way of multiplying, but one of the great steps in evolution was the discovery of a better method, namely, sexual reproduction. The gist of this is simply that during the process of body-building (by the development of the fertilised egg-cell) certain units, *the germ-cells,* do not share in forming ordinary tissues or organs, but remain apart, continuing the full inheritance which was condensed in the fertilised egg-cell. *These cells kept by themselves are the originators of the future reproductive cells of the mature animal;* they give rise to the egg-cells and the sperm-cells.

The advantages of this method are great. (1) The new generation is started less expensively, for it is easier to shed germ-cells into the cradle of the water than to separate off half of the body. (2) It is possible to start a great many new lives at once, and this may be of vital importance when the struggle for existence is very keen, and when parental care is impossible. (3) The germ-cells are little likely to be prejudicially affected by disadvantageous dints impressed on the body of the parent—little likely unless the dints have peculiarly penetrating consequences, as in the case of poisons. (4) A further advantage is implied in

the formation of two kinds of germ-cells—the ovum or egg-cell, with a considerable amount of building material and often with a legacy of nutritive yolk; the spermatozoon or sperm-cell, adapted to move in fluids and to find the ovum from a distance, thus securing change-provoking cross-fertilisation.

§ 4

The Evolution of Sex.

Another of the great steps in organic evolution was the differentiation of two different physiological types, the male or sperm-producer and the female or egg-producer. It seems to be a deep-seated difference in constitution, which leads one egg to develop into a male, and another, lying beside it in the nest, into a female. In the case of pigeons it seems almost certain, from the work of Professor Oscar Riddle, that there are two kinds of egg, a male-producing egg and a female-producing egg, which differ in their yolk-forming and other physiological characters.

In sea-urchins we often find two creatures superficially indistinguishable, but the one is a female with large ovaries and the other is a male with equally large testes. Here the physiological difference does not affect the body as a whole, but the reproductive organs or gonads only, though more intimate physiology would doubtless discover differences in the blood or in the chemical routine (metabolism). In a large number of cases, however, there are marked superficial differences between the sexes, and everyone is familiar with such contrasts as peacock and peahen, stag and hind. In such cases the physiological difference between the sperm-producer and the ovum-producer, for this is the essential difference saturates through the body and expresses itself in masculine and feminine structures and modes of behaviour. The expression of the masculine and feminine characters is in some cases under the control of hormones or chemical messengers which are carried by the blood from the reproductive organs throughout the body, and pull the trigger which brings about the development of an antler or a wattle or a decorative plume or a capacity for vocal and saltatory display. In some cases it is certain that the female carries in a latent state the masculine features, but these are kept from expressing themselves by other chemical messengers from the ovary. Of these chemical messengers more must be said later on.

Recent research has shown that while the difference between male and female is very deep-rooted, corresponding to a difference in gearing, it is not always clear-cut. Thus a hen-pigeon may be very masculine, and a cock-pigeon very feminine. The difference is in degree, not in kind.

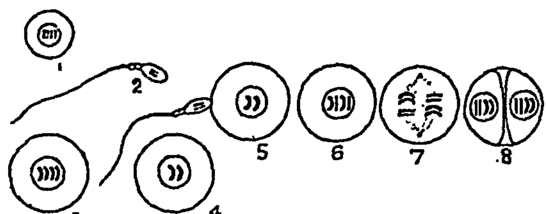


DIAGRAM ILLUSTRATING THE BEGINNING OF INDIVIDUAL LIFE.

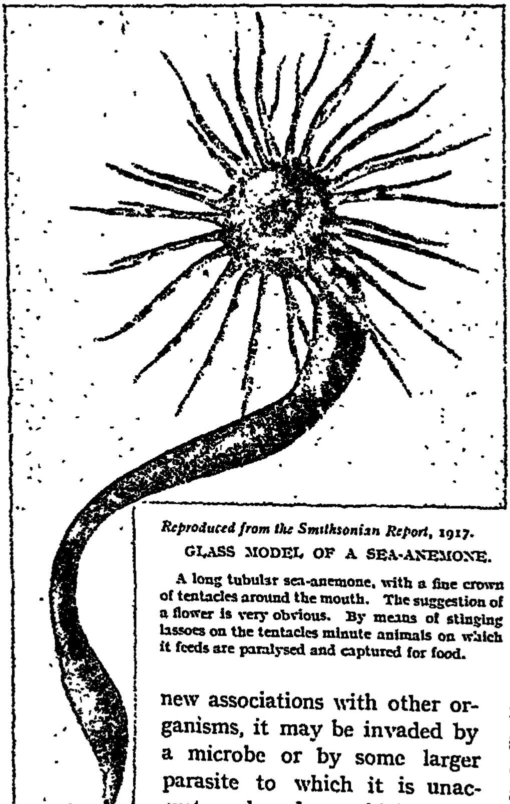
1. An immature *sperm*-cell, with 4 chromosomes (nuclear bodies) represented as rods.
2. A mature sperm-cell, with 2 chromosomes.
3. An immature *egg*-cell, with 4 chromosomes represented as curved bodies.
4. A mature egg-cell, with 2 chromosomes.
5. *The spermatozoon fertilises the ovum, introducing 2 chromosomes.*
6. The fertilised *ovum*, with 4 chromosomes, 2 of paternal origin and 2 of maternal origin.
7. The chromosomes lie at the equator, and each is split longitudinally. The centrosome introduced by the spermatozoon has divided into two centrosomes, one at each pole of the nucleus. These play an important part in the division or segmentation of the egg.
8. The fertilised egg has divided into two cells. Each cell has 2 paternal and 2 maternal chromosomes.

§ 5

What is the meaning of the universal or almost universal inevitableness of death? A Sequoia or "Big Tree" of California has been known to live for over two thousand years, but eventually it died. A centenarian tortoise has been known, and a sea-anemone sixty years of age; but eventually they die. What is the meaning of this apparently inevitable stoppage of bodily life?

The Beginning of Natural Death.

There are three chief kinds of death. (*a*) The great majority of animals come to a violent end, being devoured by others or killed by sudden and extreme changes in their surroundings. (*b*) When an animal enters a new habitat, or comes into



Reproduced from the Smithsonian Report, 1917.

GLASS MODEL OF A SEA-ANEMONE.

A long tubular sea-anemone, with a fine crown of tentacles around the mouth. The suggestion of a flower is very obvious. By means of stinging lassoes on the tentacles minute animals on which it feeds are paralysed and captured for food.

new associations with other organisms, it may be invaded by a microbe or by some larger parasite to which it is unaccustomed and to which it can offer no resistance. With many parasites a "live-and-let-live" compromise is arrived at, but new parasites are apt to be fatal, as man knows to his cost when he is bitten by a tse-tse fly which infects him with the microscopic animal (a Trypanosome) that causes Sleeping Sickness. In many animals the parasites are not troublesome as long as the host is vigorous, but if the host is out of condition the parasites may get the upper hand, as in the so-called "grouse disease," and become fatal. (*c*) But besides violent death and microbic (or parasitic) death, there is natural death. This is in great part to be regarded as the price paid for a body. A body worth having implies complexity or division of labour, and this implies certain internal furnishings of a more or less stable kind in which the effects of wear and tear are apt to accumulate. It is not the living matter itself that grows old so much as the framework in which it works—the furnishings of the vital laboratory. There are various processes of rejuvenescence, e.g. rest, repair, change, reorganisation, which work against the inevitable processes of senescence, but sooner or later the victory is with ageing. Another deep reason for natural death is to be found in the physiological expensiveness of reproduction, for many animals, from worms to eels, illustrate natural death as the nemesis of starting new lives. Now it is a very striking fact that to a large degree the simplest animals or Protozoa are exempt from natural death. They are so relatively simple that they can continually recuperate by rest and repair; they do not accumulate any bad debts. Moreover, their modes of multiplying, by dividing into two or many units, are very inexpensive physiologically. It seems that in some measure this bodily immortality of the Protozoa is shared by some simple many-celled animals like the freshwater Hydra and Planarian worms. Here is an interesting chapter in evolution, the evolution of means of evading or staving off natural death. Thus there is the well-known case of the Paloloworm of the coral-reefs where the body breaks up in liberating the germ-cells, but the head-end remains fixed in a crevice of the coral, and buds out a new body at leisure.

Along with the evolution of the ways of avoiding death should be considered also the gradual establishment of the length of life best suited to the welfare of the species, and the

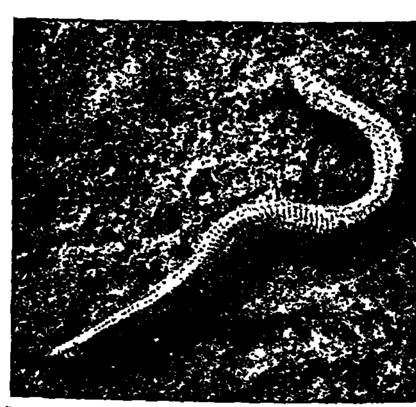


Photo: J. J. Ward, F.E.S.

EARTHWORM.

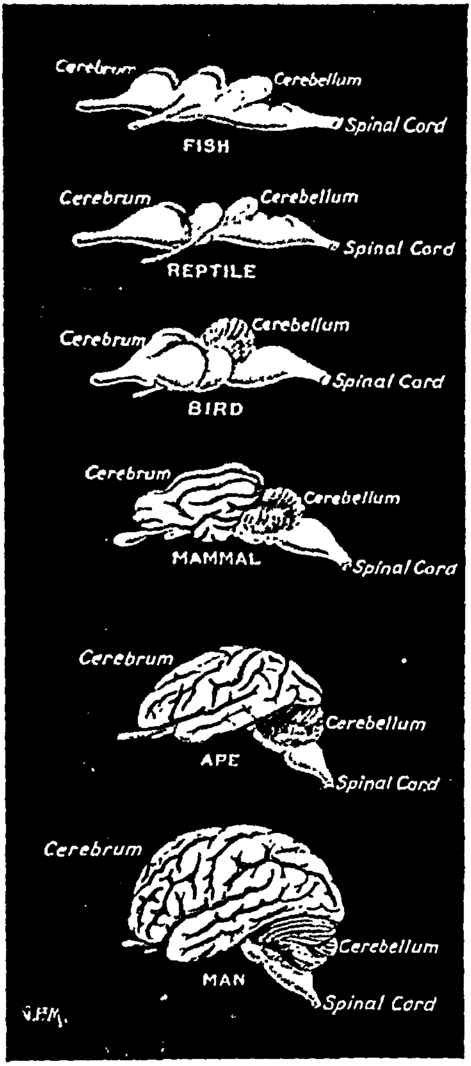
Earthworms began the profitable habit of moving with one end of the body always in front, and from worms to man the great majority of animals have bilateral symmetry.

punctuation of the life-history to suit various conditions.

§ 6

Great Acquisitions.

In animals like sea-anemones and jelly-fishes the general symmetry of the body is radial; that is to say, there is no right or left, and the body might be halved along many planes. It is a kind of symmetry well suited for sedentary or for drifting life. But worms began the profitable habit of moving with one end of the body always in front, and from worms to man the great majority of animals have bilateral symmetry. They have a right and a left side, and there is only one cut that halves the body. This kind of symmetry is suited for a more strenuous life than radial animals show; it is suited for pursuing food, for avoiding enemies, for chasing mates. And *with the establishment of bilateral symmetry must be associated the establishment of head-brains*, the beginning of which is to be found in some simple worm-types.



THIS DRAWING SHOWS THE EVOLUTION OF THE BRAIN FROM FISH TO MAN.

The Cerebrum, the seat of intelligence, increases in proportion to the other parts. In mammals it becomes more and more convoluted. The brain, which lies in one plane in fishes, becomes gradually curved on itself. In birds it is more curved than the drawing shows.

Among the other great acquisitions gradually evolved we may notice: a well-developed head with sense-organs, the establishment of large internal surfaces such as the digestive and absorptive wall of the food-canal, the origin of quickly contracting striped muscle and of muscular appendages, the formation of blood as a distributing medium throughout the body, from which all the parts take what they need and to which they also contribute

Another very important acquisition, almost confined (so far as is known) to back-boned animals, was the evolution of what are called glands of internal secretion, such as the thyroid and the supra-renal. These manufacture subtle chemical substances which are distributed by the blood throughout the body, and have a manifold influence in regulating and harmonising the vital processes. Some of these chemical messengers are called hormones, which stimulate organs and tissues to greater activity; others are called chalones, which put on a brake. Some regulate growth and others rapidly alter the pressure and composition of the blood. Some of them call into active development certain parts of the body which have been, as it were, waiting for an appropriate trigger-pulling. Thus, at the proper time, the milk-glands of a mammalian mother are awakened from their dormancy. This very interesting outcome of evolution will be dealt with in another portion of this work.

THE INCLINED PLANE OF ANIMAL BEHAVIOUR

§ 1

Before passing to a connected story of the gradual emergence of higher and higher forms of life in the course of the successive ages—the procession of life, as it may be called—it will be useful to consider the evolution of animal behaviour.

A human being begins as a microscopic fertilised egg-cell, within which there is condensed the long result of time—Man's inheritance. The long period of nine months before birth, with its intimate partnership between mother and offspring, is passed as it were in sleep, and no one can make any statement in regard to the mind of the unborn child. Even after birth the dawn of mind is as slow as it is wonderful. To begin with, there is in the ovum and early embryo no nervous system at all, and it develops very gradually from simple beginnings. Yet as mentality cannot come in from outside, we seem bound to conclude that the potentiality of it—whatever that means—resides in the individual from the very first. The particular kind of activity known to us as thinking, feeling, and willing is the most intimate part of our experience, known to us directly apart from our senses, and the possibility of that must be implicit in the germ-cell just as the genius of Newton was implicit in a very miserable specimen of an infant. Now what is true of the individual is true also of the race—there is a gradual evolution of that aspect of the living creature's activity which we call mind. We cannot put our finger on any point and say: Before this stage there was no mind. Indeed, many facts suggest the conclusion that wherever there is life there is some degree of mind—even in the plants. Or it might be more accurate to put the conclusion in another way, that the activity we call life has always in some degree an inner or mental aspect.

Evolution of Mind.

In another part of this book there is an account of the dawn of mind in backboned animals; what we aim at here is an outline of what may be called the inclined plane of animal behaviour.

A very simple animal accumulates a little store of potential energy, and it proceeds to expend this, like an explosive, by acting on its environment. It does so in a very characteristic self-preservative fashion, so that it burns without being consumed and explodes without being blown to bits. It is characteristic of the organism that it remains a going concern for a longer or shorter period—its length of life. Living creatures that expended their energy ineffectively or self-destructively would be eliminated in the struggle for existence. When a simple one-celled organism explores a corner of the field seen under a microscope, behaving to all appearance very like a dog scouring a field seen through a telescope, it seems permissible to think of something corresponding to mental endeavour associated with its activity. This impression is strengthened when an amœba pursues another amœba, overtakes it, engulfs it, loses it, pursues it again, recaptures it, and so on. What is quite certain is that the behaviour of the animalcule is not like that of a potassium pill fizzing about in a basin of water, nor like the lurching movements of a gun that has got loose and " taken charge " on board ship. Another feature is that the locomotor activity of an animalcule often shows a distinct individuality: it may swim, for instance, in a loose spiral.

But there is another side to vital activity besides acting upon the surrounding world; the living creature is acted on by influences from without. The organism acts on its environment; that is the one side of the shield: the environment acts upon the organism; that is the other side. If we are to see life whole we must recognise these two sides of what we call living, and it is missing an important part of the history of animal life if we fail to see that evolution implies becoming more advantageously sensitive to the environment, making more of its influences, shutting out profitless stimuli, and opening more gateways to knowledge. The bird's world is a larger and finer world than an earthworm's; the world means more to the bird than to the worm.

Simple creatures act with a certain degree of spontaneity on their environment, and they likewise react *effectively* to surrounding stimuli. Animals come to have definite " answers back," sometimes several, sometimes only one, as in

The Trial and Error Method.

OKAPI AND GIRAFFE.

The Okapi is one of the great zoological discoveries. It gives a good idea of what the Giraffe's ancestors were like. The Okapi was unknown until discovered in 1900 by Sir Harry Johnston in Central Africa, where these strange animals have probably lived in dense forests from time immemorial.

[illegible]

[illegible]

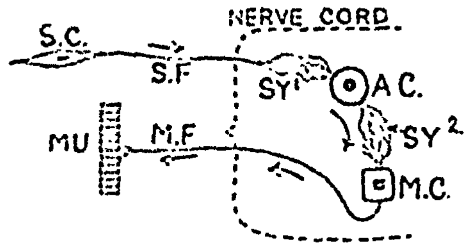
[illegible] When the creature profits by experience [illegible]

An [illegible] we find the beginnings of reflex actions, and a considerable part of the behaviour of the lower animals is reflex. That is to say,

Reflex Actions.

there are laid down in the animal in the course of its development certain prearrangements of nerve-cells and muscle-cells which secure that a fit and proper answer is given to a frequently recurrent stimulus. An earthworm half out of its burrow becomes aware of the light tread of a thrush's foot, and jerks itself back into its hole before anyone can say "reflex action." What is it that happens?

Certain sensory nerve-cells in the earthworm's skin are stimulated by vibrations in the earth; the message travels down a sensory nerve-fibre from each of the stimulated cells and enter the nerve-cord. The sensory fibres come into vital connection with branches of intermediary, associative, or communicating cells, which are likewise connected with motor nerve-cells. To these the message is thus shunted. From the motor nerve-cells an impulse or command travels by motor nerve-fibres, one from each cell, to the muscles, which contract. If this took as long to happen as it takes to describe, even in outline, it would not be of much use to the earthworm. But the motor answer follows the sensory stimulus almost instantaneously. The great advantage of establishing or entering these reflex channels is that the answers are practically ready-made or inborn, not requiring to be learned. It is not necessary that the brain should be stimulated if there is a brain; [illegible] the animal will to act, though in certain cases it may by means of higher controlling



[illegible]

1. [illegible]
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nerve-centres keep the natural reflex response from being given, as happens, for instance, when we control a cough or a sneeze on some solemn occasion. The evolutionary method, if we may use the expression, has been to enregister ready-made responses; and as we ascend the animal kingdom, we find reflex actions becoming complicated and often linked together, so that the occurrence of one pulls the trigger of another, and so on in a chain. The behaviour of the insectivorous plant called Venus' fly-trap when it shuts on an insect is like a reflex action in an animal, but plants have no definite nervous system.

A somewhat higher level on the inclined plane is illustrated by what are called "tropisms,"

What are called Tropisms.

obligatory movements which the animal makes, adjusting its whole body so that physiological equilibrium results in relation to gravity, pressure, currents, moisture, heat, light, electricity, and surfaces of contact. A moth is flying past a candle; the eye next the light is more illumined than the other; a physiological inequilibrium

results, affecting nerve-cells and muscle-cells; the outcome is that the moth automatically

Photo: J. J. Ward, F.E.S.

VENUS' FLY-TRAP.

One of the most remarkable plants in the world, which captures its prey by means of a trap formed from part of its leaf. It has been induced to snap at and hold a bristle. If an insect lighting on the leaf touches one of six very sensitive hairs, which pull the trigger of the movement, the two halves of the leaf close rapidly and the fringing teeth on the margin interlock, preventing the insect's escape. Then follows an exudation of digestive juice.

adjusts its flight so that both eyes become equally illumined; in doing this it often flies into the candle.

It may seem bad business that the moth should fly into the candle, but the flame is an utterly artificial item in its environment to which no one can expect it to be adapted. These tropisms play an important rôle in animal behaviour.

§ 2

Instinctive Behaviour.

On a higher level is instinctive behaviour, which reaches such remarkable perfection in ants, bees, and wasps. In its typical expression instinctive behaviour depends on inborn capacities; it does not require to be learned; it is independent of practice or experience, though it may be improved by both; it is shared equally by all members of the species of the same sex (for the female's instincts are often different from the male's);

Photo: British Museum (Natural History).

THE YUCCA MOTH.

The Yucca Moth, emerging from her cocoon, flies at night to a Yucca flower and collects pollen from the stamens, holding a little ball of it in her mouth-parts. She then visits another flower and lays an egg in the seed-box. After this she applies the pollen to the tip of the pistil, thus securing the fertilisation of the flower and the growth of the ovules in the pod. Yucca flowers in Britain do not produce seeds because there are no Yucca Moths.

it refers to particular conditions of life that are of vital importance, though they may occur only once in a lifetime. The female Yucca Moth emerges from the cocoon when the Yucca flower puts forth its bell-like blossoms. She flies to a flower, collects some pollen from the stamens, kneads it into a pill-like ball, and stows this away under her chin. She flies to an older Yucca flower and lays her eggs in some of the ovules within the seed-box, but before she does so she has to deposit on the stigma the ball of pollen. From this the pollen-tubes grow down and the pollen-nucleus of a tube fertilises the egg-cell in an ovule,

so that the possible seeds become real seeds, for it is only a fraction of them that the Yucca Moth has destroyed by using them as cradles for her eggs. Now it is plain that the Yucca Moth has no individual experience of Yucca flowers, yet she secures the continuance of her race by a concatenation of actions which form part of her instinctive repertory.

From a physiological point of view instinctive behaviour is like a chain of compound reflex actions, but in some cases, at least, there is reason to believe that the behaviour is suffused with awareness and backed by endeavour. This is suggested in exceptional cases where the stereotyped routine is departed from to meet exceptional conditions. It should also be noted that just as ants, hive bees, and wasps exhibit in most cases purely instinctive behaviour, but move on occasion on the main line of trial and error or of experimental initiative, so among birds and mammals the intelligent behaviour is sometimes replaced by instinctive routine. Perhaps there is no instinctive behaviour without a spice of intelligence, and no intelligent behaviour without an instinctive element. The old view that instinctive behaviour was originally intelligent, and that instinct is "lapsed intelligence," is a tempting one, and is suggested by the way in which habitual intelligent actions cease in the individual to require intelligent control, but it rests on the unproved hypothesis that the acquisitions of the individual can be entailed on the race. It is almost certain that instinct is on a line of evolution quite different from intelligence, and that it is nearer to the inborn inspirations of the calculating boy or the musical genius than to the plodding methods of intelligent learning.

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A SPIDER SUNNING HER EGGS.

A kind of spider, called Lycosa, lying head downwards at the edge of her nest, and holding her silken cocoon—the bag containing the eggs—up towards the sun in her hindmost pair of legs. This extraordinary proceeding is believed to assist in the hatching.

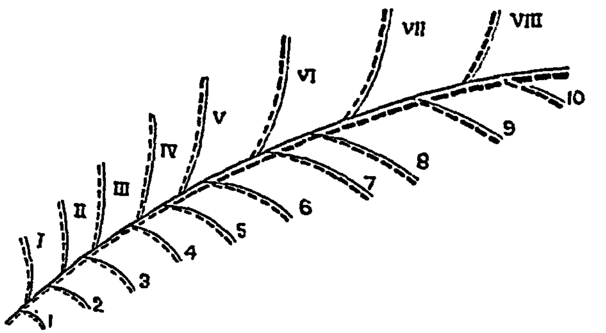
Animal Intelligence.

The higher reaches of the inclined plane of behaviour show intelligence in the strict sense. They include those kinds of behaviour which cannot be described without the suggestion that the animal makes some sort of perceptual inference, not only profiting by experience but learning by ideas. Such intelligent actions show great individual variability; they are plastic and adjustable in a manner rarely hinted at in connection with instincts where routine cannot be departed from without the creature being nonplussed; they are not bound up with particular circumstances as instinctive actions

are, but imply an appreciative awareness of relations.

When there is an experimenting with general ideas, when there is *conceptual* as contrasted with *perceptual* inference, we speak of Reason, but there is no evidence of this below the level of man. It is not, indeed, always that we can credit man with rational conduct, but he has the possibility of it ever within his reach.

Animal instinct and intelligence will be illustrated in another part of this work. We are here concerned simply with the general question of the evolution of behaviour. There is a main line of tentative experimental behaviour



INCLINED PLANE OF ANIMAL BEHAVIOUR.

Diagram illustrating animal behaviour. The main line represents the general life of the creature. On the upper side are activities implying initiative, on the lower side actions which are almost automatic.

Upper Side.—I. Energetic actions. II. Simple tentatives. III. Trial-and-error methods. IV. Non-intelligent experiments. V. Experiential "learning." VI. Associative "learning." VII. Intelligent behaviour. VIII. Rational conduct (man).

Lower Side.—1. Reactions to environment. 2. Enregistered reactions. 3. Simple reflex actions. 4. Compound reflex actions. 5. Tropisms. 6. Enregistered rhythms. 7. Simple instincts. 8. Chain instincts. 9. Instinctive activities influenced by intelligence. 10. Subconscious cerebration at a high level (man).

both below and above the level of intelligence, and it has been part of the tactics of evolution to bring about the hereditary enregistration of capacities of effective response, the advantages being that the answers come more rapidly and that the creature is left free, if it chooses, for higher adventures.

There is no doubt as to the big fact that in the course of evolution animals have shown an increasing complexity and masterfulness of behaviour, that they have become at once more controlled and more definitely free agents, and that the inner aspect of the behaviour—experimenting, learning, thinking, feeling, and willing—has come to count for more and more.

§ 3

Evolution of Parental Care.

Mammals furnish a crowning instance of a trend of evolution which expresses itself at many levels—the tendency to bring forth the young at a well-advanced stage and to an increase of parental care associated with a decrease in the number of offspring. There is a British starfish called *Luidia* which has two hundred millions of eggs in a year, and there are said to be several millions of eggs in conger-eels and some other fishes. These illustrate the spawning method of solving the problem of survival. Some animals are naturally prolific, and the number of eggs which they sow broadcast in the waters allows for enormous infantile mortality and obviates any necessity for parental care.

But some other creatures, by nature less prolific, have found an entirely different solution of the problem. They practise parental care and they secure survival with greatly economised reproduction. This is a trend of evolution particularly characteristic of the higher animals. So much so that Herbert Spencer formulated the generalisation that the size and frequency of the animal family is in inverse ratio to the degree of evolution to which the animal has attained.

Now there are many different methods of parental care which secure the safety of the young, and one of these is called viviparity. The young ones are not liberated from the parent until they are relatively well advanced and more or less able to look after themselves. This gives the young a good send-off in life, and their chances of death are greatly reduced. In other words, the animals that have varied in the direction of economised reproduction may keep their foothold in the struggle for existence if they have varied at the same time in the direction of parental care. In other cases it may have worked the other way round.

In the interesting archaic animal called *Peripatus*, which has to face a modern world too severe for it, one of the methods of meeting

THE HOATZIN INHABITS BRITISH GUIANA.

The newly-hatched bird has claws on its thumb and first finger and so is enabled to climb on the branches of trees with great dexterity until such time as the wings are strong enough to sustain it in flight.

the environing difficulties is the retention of the offspring for many months within the mother, so that it is born a fully-formed creature. There are only a few offspring at a time, and, although there are exceptional cases like the summer green-flies, which are very prolific though viviparous, the general rule is that viviparity is associated with a very small family. The case

Photograph, from the British Museum (Natural History), of a drawing by Mr E. Wilson.

PERIPATUS.

A widely-distributed old-fashioned type of animal, somewhat like a permanent caterpillar. It has affinities both with worms and with insects It has a velvety skin, minute diamond-like eyes, and short stump like legs. A defenceless, weaponless animal, it comes out at night, and is said to capture small insects by squirting jets of slime from its mouth.

of flowering plants stands by itself, for although they illustrate a kind of viviparity, the seeds being embryos, an individual plant may have a large number of flowers and therefore a huge family.

Viviparity naturally finds its best illustrations among terrestrial animals, where the risks to the young life are many, and it finds its climax among mammals.

Now it is an interesting fact that the three lowest mammals, the Duckmole and two Spiny Ant-eaters, lay eggs, i.e. are oviparous; that the Marsupials, on the next grade, bring forth their young, as it were, prematurely, and in most cases stow them away in an external pouch; while all the others—the Placentals—show a more prolonged antenatal life and an intimate partnership between the mother and the unborn young.

§ 4

There is another way of looking at the sublime process of evolution. It has implied a mastery of all the possible haunts of life; it has been a progressive conquest of the environment.

1. It is highly probable that living organisms found their first foothold in the stimulating conditions of the shore of the sea—the shallow water, brightly illumined, seaweed-growing shelf fringing the Continents. This littoral zone was a propitious environment, where sea and fresh water, earth and air all meet, where there is stimulating change, abundant oxygenation, and a copious supply of nutritive material in what the streams bring down and in the rich seaweed vegetation.

It is not an easy haunt of life, but none the worse for that, and it is tenanted to-day by representatives of practically every class of animals, from infusorians to sea-shore birds and mammals.

The Cradle of the Open Sea.

2. The open-sea or pelagic haunt includes all the brightly illumined surface waters beyond the shallow water of the shore area. It is perhaps the easiest of all the haunts of life, for there is no crowding, there is considerable uniformity, and an abundance of food for animals is afforded by the inexhaustible floating "sea-meadows" of microscopic Algæ. These are reincarnated in minute animals like the open-sea crustaceans, which again are utilised by fishes, these in turn making life possible for higher forms like carnivorous turtles and toothed whales. It is quite possible that the open sea was the original cradle of life, and perhaps Professor Church is right in picturing a long period of pelagic life before there was any sufficiently shallow water to allow the floating plants to anchor. It is rather in favour of this view that many shore

Photo: W. S. Berridge, F.Z.S.

ROCK KANGAROO CARRYING ITS YOUNG IN A POUCH.

The young are born so helpless that they cannot even suck. The mother places them in the external pouch, and fitting their mouths on the teats injects the milk. After a time the young ones go out and in as they please.

animals, such as crabs and starfishes, spend their youthful stages in the relatively safe cradle of the open sea, and only return to the more strenuous conditions of their birthplace after

they have gained considerable strength of body. It is probably safe to say that the honour of being the original cradle of life lies between the shore of the sea and the open sea.

3. A third haunt of life is the floor of the Deep Sea, the abyssal area, which occupies more than a half of the surface of the globe. It is a region of extreme cold—an eternal winter; of utter darkness—an eternal night—relieved only by the fitful gleams of "phosphorescent" animals; of enormous pressure—2½ tons on the square inch at a depth of 2,500 fathoms; of profound calm, unbroken silence, immense monotony. And as there are no plants in the great abysses, the animals must live on one another, and, in the long run, on the rain of moribund animalcules which sink from the surface through the miles of water. It seems a very unpromising haunt of life, but it is abundantly tenanted, and it gives us a glimpse of the insurgent nature of the living creature that the difficulties of the Deep Sea should have been so effectively conquered. It is probable that the colonising of the great abysses took place in relatively recent times, for the fauna does not include many very antique types. It is practically certain that the colonisation was due to littoral animals which followed the food-debris, millennium after millennium, further and further down the long slope from the shore.

The Great Deeps.

[illegible]

PROFESSOR THOMAS HENRY HUXLEY (1825-95).

One of the most distinguished of zoologists, with unsurpassed gifts as a teacher and expositor. He did great service in gaining a place for science in ordinary education and in popular estimation. No one championed Evolutionism with more courage and skill.

4. A fourth haunt of life is that of the freshwaters, including river and lake, pond and pool, swamp and marsh. It may have been colonised by gradual migration up estuaries and rivers, or by more direct passage from the seashore into the brackish swamp. Or it may have been in some cases that landlocked corners of ancient seas became gradually turned into freshwater basins. The animal population of the freshwaters is very representative, and is diversely adapted to meet the characteristic contingencies—the risk of being dried up, the risk of being frozen hard in winter, and the risk of being left high and dry after floods, or of being swept down to the sea.

The Freshwaters.

5. The terrestrial haunt has been invaded age after age by contingents from the sea or from the freshwaters. We must recognise the worm invasion, which led eventually to the making of the fertile soil, the invasion due to air-breathing Arthropods, which led eventually to the important linkage between flowers and their insect visitors, and the invasion due to air-breathing Amphibians, which led eventually to the higher terrestrial animals and to the development of intelligence and family affection. Besides these three great invasions, there were minor ones such as that leading to land-snails, for there has been a widespread and persistent tendency among aquatic animals to try to possess the dry land.

Conquest of the Dry Land.

Getting on to dry land had a manifold significance.

It implied getting into a medium with a much larger supply of oxygen than there is dissolved in the water. But the oxygen of the air is more difficult to capture, especially when the skin becomes hard or well protected, as it is almost bound to become in animals living on dry ground. Thus this leads to the development

of *internal surfaces*, such as those of lungs, where the oxygen taken into the body may be absorbed by the blood. In most animals the blood goes to the surface of oxygen-capture; but in insects and their relatives there is a different idea—of taking the air to the blood or in greater part to the area of oxygen-combustion, the living tissues. A system of branching air-tubes takes air into every hole and corner of the insect's body, and this thorough aeration is doubtless in part the secret of the insect's intense activity. The blood never becomes impure.

The conquest of the dry land also implied a predominance of that kind of locomotion which may be compared to punting, when the body is pushed along by pressing a lever against a hard substratum. And it also followed that with few exceptions the body of the terrestrial animal tended to be compact, readily lifted off the ground by the limbs or adjusted in some other way so that there may not be too large a surface trailing on the ground. An animal like a jelly-fish, easily supported in the water, would be impossible on land. Such apparent exceptions as earthworms, centipedes, and snakes are not difficult to explain, for the earthworm is a burrower which eats its way through the soil, the centipede's long body is supported by numerous hard legs, and the snake pushes itself along by means of the large ventral scales to which the lower ends of very numerous ribs are attached.

Methods of Mastering the Difficulties of Terrestrial Life.

A great restriction attendant on the invasion of the dry land is that locomotion becomes limited to one plane, namely, the surface of the earth. This is in great contrast to what is true in the water, where the animal can move up or down, to right or to left, at any angle and in three dimensions. It surely follows from this that the movements of land animals must be rapid and precise, unless, indeed, safety is secured in some other way. Hence it is easy to understand why most land animals have very finely developed striped muscles, and why a beetle running on the ground has far more numerous muscles than a lobster swimming in the sea.

Land animals were also handicapped by the risks of drought and of frost, but these were met by defences of the most diverse description, from the hairs of woolly caterpillars to the fur of mammals, from the carapace of tortoises to the armour of armadillos. In other cases, it is hardly necessary to say, the difficulties may be met in other ways, as frogs meet the winter by falling into a lethargic state in some secluded retreat.

Another consequence of getting on to dry land is that the eggs or young can no longer be set free anyhow, as is possible when the animal is surrounded by water, which is in itself more or less of a cradle. If the eggs were laid or the young liberated on dry ground, the chances are many that they would be dried up or devoured. So there are numerous ways in which land animals secure the safety of their young, e.g. by burying them in the ground, or by hiding them in nests, or by carrying them about for a prolonged period either before or after birth. This may mean great safety for the young, this may make it possible to have only a small family, and this may tend to the evolution of parental care and the kindly emotions. Thus it may be understood that from the conquest of the land many far-reaching consequences have followed.

Finally, it is worth dwelling on the risks of terrestrial life, because they enable us better to understand why so many land animals have become burrowers and others climbers of trees, why some have returned to the water and others have taken to the air. It may be asked, perhaps, why the land should have been colonised at all when the risks and difficulties are so great. The answer must be that necessity and curiosity are the mother and father of invention. Animals left the water because the pools dried up, or because they were overcrowded, or because of inveterate enemies, but also because of that curiosity and spirit of adventure which, from first to last, has been one of the spurs of progress.

Conquering the Air.

6. The last great haunt of life is the air, a mastery of which must be placed to the credit of insects, Pterodactyls, birds, and bats. These have been the successes, but it should be noted that there have been many brilliant failures, which have not attained to much more than parachuting. These include the Flying Fishes, which take leaps from the water and are carried

AN ILLUSTRATION SHOWING VARIOUS METHODS OF FLYING AND SWOOPING.

Gull, with a feather-wing, a true flier. Fox-bat, with a skin-wing, a true flier. Flying Squirrel, with a parachute of skin, able to swoop from tree to tree, but not to fly. Flying Fish, with pectoral fins used as volplanes in a great leap due to the tail. To some extent able to sail in albatross fashion.

for many yards and to considerable heights, holding their enlarged pectoral fins taut or with little more than a slight fluttering. There is a so-called Flying Frog (*Rhacophorus*) that skims from branch to branch, and the much more effective Flying Dragon (*Draco volans*) of the Far East, which has been mentioned already. Among mammals there are Flying Phalangers, Flying Lemurs, and more besides, all attaining to great skill as parachutists, and illustrating the endeavour to master the air which man has realised in a way of his own.

The power of flight brings obvious advantages. A bird feeding on the ground is able to evade the stalking carnivore by suddenly rising into the air; food and water can be followed rapidly and to great distances; the eggs or the young can be placed in safe situations; and birds in their migrations have made a brilliant conquest both of time and space. Many of them know no winter in their year, and the migratory flight of the Pacific Golden Plover from Hawaii to Alaska and back again does not stand alone.

THE PROCESSION OF LIFE THROUGH THE AGES

§ 1

The Rock Record.

How do we know when the various classes of animals and plants were established on the earth? How do we know the order of their appearance and the succession of their advances? The answer is: by reading the Rock Record. In the course of time the crust of the earth has been elevated into continents and depressed into ocean-troughs, and the surface of the land has been buckled up into mountain ranges and folded in gentler hills and valleys. The high places of the land have been weathered by air and water in many forms, and the results of the weathering have been borne away by rivers and seas, to be laid down again elsewhere as deposits which eventually formed sandstones, mudstones, and similar sedimentary rocks. Much of the material of the original crust has thus been broken down and worked up again many times over, and if the total thickness of the sedimentary rocks is added up it amounts, according to some geologists, to a total of 67 miles. In most cases, however, only a small part of this thickness is to be seen in one place, for the deposits were usually formed in limited areas at any one time.

The Use of Fossils.

When the sediments were accumulating age after age, it naturally came about that remains of the plants and animals living at the time were buried, and these formed the fossils by the aid of which it is possible to read the story of the past. By careful piecing together of evidence the geologist is able to determine the order in which the different sedimentary rocks were laid down, and thus to say, for instance, that the Devonian period was the time of the origin of Amphibians. In other cases the geologist utilises the fossils in his attempt to work out the order of the strata when these have been much disarranged. For the simpler fossil forms of any type must be older than those that are more complex. There is no vicious circle here, for the general succession of strata is clear, and it is quite certain that there were fishes before there were amphibians, and amphibians before there were reptiles, and reptiles before there were birds and mammals. In certain cases, e.g. of fossil horses and elephants, the actual historical succession has been clearly worked out.

If the successive strata contained good samples of all the plants and animals living at the time when the beds were formed, then it would be easy to read the record of the rocks, but many animals were too soft to become satisfactory fossils, many were eaten or dissolved away, many were destroyed by heat and pressure, so that the rock record is like a library very much damaged by fire and looting and decay.

§ 2

The long history of the earth and its inhabitants is conveniently divided into eras. Thus,

The Geological Time-table.

just as we speak of the ancient, mediæval, and modern history of mankind, so we may speak of Palæozoic, Mesozoic, and Cenozoic eras in the history of the earth as a whole.

BARON CUVIER, 1769-1832.

One of the founders of modern Comparative Anatomy. A man of gigantic intellect, who came to Paris as a youth from the provinces, and became the director of the higher education of France and a peer of the Empire. He was opposed to Evolutionist ideas, but he had anatomical genius.

Geologists cannot tell us except in an approximate way how long the process of evolution has taken. One of the methods is to estimate how long has been required for the accumulation of the salts of the sea, for all these have been dissolved out of the rocks since rain began to fall on the earth. Dividing the total amount of saline matter by what is contributed every year in modern times, we get about a hundred million years as the age of the sea. But as the present rate of salt-accumulation is probably much greater than it was during many of the geological periods, the prodigious age just mentioned is in all likelihood far below the mark. Another method is to calculate how long it would take to form the sedimentary rocks, like sandstones and mudstones, which have a *total* thickness of over fifty miles, though the *local* thickness is rarely over a mile. As most of the materials have come from the weathering of the earth's crust, and as the annual amount of weathering now going on can be estimated, the time required for the formation of the sedimentary rocks of the world can be approximately calculated. There are some other ways of trying to tell the earth's age and the length of the successive periods, but no certainty has been reached.

The eras marked on the table (page 52) as *before the Cambrian* correspond to about thirty-two miles of thickness of strata; and all the subsequent eras with fossil-bearing rocks to a thickness of about twenty-one miles—in itself an astounding fact. Perhaps thirty million years must be allotted to the Pre-Cambrian eras, eighteen to the Palæozoic, nine to the Mesozoic, three to the Cenozoic, making a grand total of sixty millions.

The Establishment of Invertebrate Stocks.

It is an astounding fact that at least half of geological time (the Archæozoic and Proterozoic eras) passed before there were living creatures with parts sufficiently hard to form fossils. In the latter part of the Proterozoic era there are traces of one-celled marine animals (Radiolarians) with shells of flint, and of worms that wallowed in the primal mud. It is plain that as regards the most primitive creatures the rock record tells us little.

The rarity of direct traces of life in the oldest rocks is partly due to the fact that the primitive animals would be of delicate build, but it must also be remembered that the ancient rocks have been profoundly and repeatedly changed by pressure and heat, so that the traces which did exist would be very liable to obliteration. And if it be asked what right we have to suppose the presence of living creatures in the absence or extreme rarity of fossils, we must point to great accumulations of limestone which indicate the existence of calcareous algæ, and to deposits of iron which probably indicate the activity of iron-forming Bacteria. Ancient beds of graphite similarly suggest that green plants flourished in these ancient days.

§ 3

The *Cambrian* period was the time of the establishment of the chief stocks of backboneless animals, such as sponges, jellyfishes, worms,

sea-cucumbers, lamp-shells, trilobites, crustaceans, and molluscs. There is something very eloquent in the broad fact that the peopling of the seas had definitely begun some thirty million years ago, for Professor H. F. Osborn points out that in the Cambrian period there was already a colonisation of the shore of the sea, the open sea, and the deep waters.

The Era of Ancient Life (Palæozoic).

The *Ordovician* period was marked by abundant representation of the once very successful class of Trilobites—jointed-footed, antenna-bearing, segmented marine animals, with numerous appendages and a covering of chitin. They died away entirely with the end of the Palæozoic era. Also very notable was the abundance of predatory cuttlefishes, the bullies of the ancient seas. But it was in this period that the first backboned animals made their appearance—an epoch-making step in evolution. In other words, true fishes were evolved—destined in the course of ages to replace the cuttlefishes (which are mere molluscs) in dominating the seas.

In the *Silurian* period, in which the peopling of the seas went on apace, there was the first known attempt at colonising the dry land. For in Silurian rocks there are fossil scorpions, and that implies ability to breathe dry air—by means of internal surfaces, in this case known as lung-books. It was also towards the end of the Silurian, when a period of great aridity set in, that fishes appeared related to our mud-fishes or double-breathers (Dipnoi), which have lungs as well as gills. This, again, meant utilising dry air, just as the present-day mud-fishes do when the water disappears from the pools in hot weather. The lung-fishes or mud-fishes of to-day are but three in number, one in Queensland, one in

RECENT TIMES		Human civilisation.
CENOZOIC ERA	PLEISTOCENE OR GLACIAL TIME	Last Great Ice Age.
	MIOCENE AND PLIOCENE TIMES	Emergence of Man.
	EOCENE AND OLIGOCENE TIMES	Rise of higher mammals.
MESOZOIC ERA	CRETACEOUS PERIOD	Rise of primitive mammals, flowering plants, and higher insects.
	JURASSIC PERIOD	Rise of birds and flying reptiles.
	TRIASSIC PERIOD	Rise of dinosaur reptiles.
PALÆOZOIC ERA	PERMIAN PERIOD	Rise of reptiles.
	CARBONIFEROUS PERIOD	Rise of insects.
	DEVONIAN PERIOD	First amphibians.
	SILURIAN PERIOD	Land animals began.
	ORDOVICIAN PERIOD	First fishes.
	CAMBRIAN PERIOD	Peopling of the sea.
PROTEROZOIC AGES		Many of the Backboneless stocks began.
ARCHÆOZOIC AGES		Living creatures began to be upon the earth.
FORMATIVE TIMES		Making of continents and ocean-basins.
		Beginnings of atmosphere and hydrosphere.
		Cooling of the earth.
		Establishment of the solar system.

Jellyfish.

Sponges.

Starfish.

Trilobites.

Crinoids or Sea lilies.

Water fleas.

From Knipe's "Nebula to Man."

ANIMALS OF THE CAMBRIAN PERIOD.

e.g. Sponges, Jellyfish, Starfish, Sea-lilies, Water-fleas, and Trilobites.

South America, and one in Africa, but they are extremely interesting "living fossils," binding the class of fishes to that of amphibians. It is highly probable that the first invasion of the dry land should be put to the credit of some adventurous worms, but the second great invasion was certainly due to air-breathing Arthropods, like the pioneer scorpion we mentioned.

Photo: British Museum (Natural History).

THE GAMBIAN MUD-FISH, PROTOPTERUS.

It can breathe oxygen dissolved in water by its gills; it can also breathe dry air by means of its swim-bladder, which has become a lung. It is a *double-breather*, showing evolution in process. For seven months of the year, the dry season, it can remain inert in the mud, getting air through an open pipe to the surface. When water fills the pools it can use its gills again. Mud-nests or mud encasements with the lung-fish inside have often been brought to Britain and the fish when liberated were quite lively.

The *Devonian* period, including that of the Old Red Sandstone, was one of the most significant periods in the earth's history. For it was the time of the establishment of flowering plants upon the earth and of terrestrial backboned animals. One would like to have been the discoverer of the Devonian footprint of *Thinopus*, the first known Amphibian foot-print—an eloquent vestige of the third great invasion of the dry land. It was probably from a stock of Devonian lung-fishes that the first Amphibians sprang, but it was not till the next period that they came to their own. While they were still feeling their way, there was a remarkable exuberance of shark-like and heavily armoured fishes in the Devonian seas.

EVOLUTION OF LAND ANIMALS

§ 1

The *Carboniferous* period was marked by a mild moist climate and a luxuriant vegetation in the swampy low grounds. It was a much less strenuous time than the Devonian period; it was like a very long summer. There were no trees of the type we see now, but there were forests of club-mosses and horse-tails which grew to a gigantic size compared with their pigmy representatives of to-day. In these forests the jointed-footed invaders of the dry land ran riot in the form of centipedes, spiders, scorpions, and insects, and on these the primeval Amphibians fed. The appearance of insects made possible a new linkage of far-reaching importance, namely, the cross-fertilisation of flowering plants by their insect visitors, and from this time onwards it may be said that flowers and their visitors have evolved hand in hand. Cross-fertilisation is much surer by insects than by the wind, and cross-fertilisation is more advantageous than self-fertilisation because it promotes both fertility and plasticity. It was probably in this period that *coloured* flowers—attractive to insect-visitors—began to justify themselves as beauty become useful, and began to relieve the monotonous green of the horsetail and club-moss forests, which covered great tracts of the earth for millions of years. In the Carboniferous forests there were also land-snails, representing one of the minor invasions of the dry land, tending on the whole to check vegetation. They, too, were probably preyed upon by the Amphibians, some of which attained a large size. Each age has had its giants, and those of the Carboniferous were Amphibians called Labyrinthodonts, some of which were almost as big as donkeys. It need hardly be said that it was in this period that most of the Coal-measures were laid down by the immense accumulation of the spores and debris of the club-moss forests. Ages afterwards, it was given to man to tap this great source of energy—traceable back to the sunshine of millions of years ago. Even then it was true that no plant or animal lives or dies to itself!

Giant Amphibians and Coal-measures.

As Amphibians had their Golden Age in the Carboniferous period we may fitly use this opportunity of indicating the advances in evolution which the emergence of Amphibians implied. (1) In the first place the passage from water to dry land was the beginning of a higher and more promiseful life, taxed no doubt by increased difficulties. The natural question rises why animals should have migrated from water to dry land at all when great difficulties were involved in the transition. The answers must be: (*a*) that local drying up of water-basins or elevations of the land surface often made the old haunts untenable; (*b*) that there may have been great congestion and competition in the old quarters; and (*c*) that there has been an undeniable endeavour after well-being throughout the history of animal life. In the same way with mankind, migrations were prompted by the setting in of prolonged drought, by over-population, and by the spirit of adventure. (2) In Amphibians for the first time the non-digitate paired fins of fishes were replaced by limbs with fingers and toes. This implied an advantageous power of grasping, of holding firm, of putting food into the mouth, of feeling things in three dimensions. (3) We cannot be positive in regard to the soft parts of the ancient Amphibians known only as fossils, but if they were in a general way like the frogs and toads, newts and salamanders of the present day, we may say that they made among other acquisitions the following: true ventral lungs, a three-chambered heart, a movable tongue, a drum to the ear, and lids to the eyes. It is very interesting to find that though the tongue of the tadpole has some muscle-fibres in it, they are not strong enough to effect movement,

The Acquisitions of Amphibians.

recalling the tongue of fishes, which has not any muscles at all. Gradually, as the tadpole becomes a frog, the muscle-fibres grow in strength, and make it possible for the full-grown creature to shoot out its tongue upon insects. This is probably a recapitulation of what was accomplished in the course of millennia in the history of the Amphibian race.

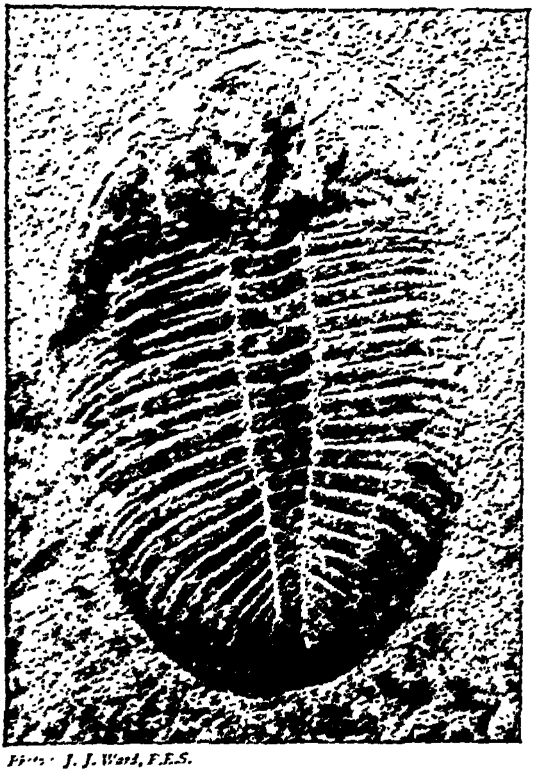


Photo: J. J. Ward, F.E.S.

A TRILOBITE.

Trilobites were ancient seashore animals, abundant from the Upper Cambrian to the Carboniferous eras. They have no direct descendants today. They were jointed-footed animals, allied to Crustaceans and perhaps also to King-crabs. They were able to roll themselves up in their ring-armour.

(4) Another acquisition made by Amphibians was a voice, due, as in ourselves, to the rapid passage of air over taut membranes (vocal cords) stretched in the larynx. It is an interesting fact that for millions of years there was upon the earth no sound of life at all, only the noise of wind and wave, thunder and avalanche. Apart from the instrumental music of some insects, perhaps beginning in the Carboniferous, the first vital sounds were due to Amphibians, and theirs certainly was the first voice—surely one of the great steps in organic evolution.

The first use of the voice was probably that indicated by our frogs and toads—it serves as a sex-call. That is the meaning of the trumpeting with which frogs herald the spring, and it is often only in the males that the voice is well developed. But if we look forward, past Amphibians altogether, we find the voice becoming a maternal call helping to secure the safety of the young—a use very obvious when young birds squat motionless at the sound of the parent's danger-note. Later on, probably, the voice became an infantile call, as when the unhatched

Evolution of the Voice.

crocodile pipes from within the deeply buried egg, signalling to the mother that it is time to be unearthed. Higher still the voice expresses emotion, as in the song of birds, often outside the limits of the breeding time. Later still, particular sounds become *words*, signifying particular things or feelings, such as "food," "danger," "home," "anger," and "joy." Finally words become a medium of social intercourse and as symbols help to make it possible for man to reason.

§ 2

In the *Permian* period reptiles appeared, or perhaps one should say, began to assert themselves. That is to say, there was an emergence of backboned animals which were free from water and relinquished the method of breathing by gills, which Amphibians retained in their young stages at least. The unhatched or unborn reptile breathes by means of a vascular hood spread underneath the egg-shell and absorbing dry air from without. It is an interesting point that this vascular hood, called the allantois, is represented in the Amphibians by an unimportant bladder growing out from the hind end of the food-canal. A great step in evolution was implied in the origin of this antenatal hood or fœtal membrane and another one—of protective significance—called the amnion, which forms a water-bag over the delicate embryo. The step meant total emancipation from the water and from gill-breathing, and the two fœtal membranes, the amnion and the allantois, persist not only in all reptiles but in birds and mammals as well. These higher Vertebrates are therefore called Amniota in contrast to the Lower Vertebrates or Anamnia (the Amphibians, Fishes, and primitive types).

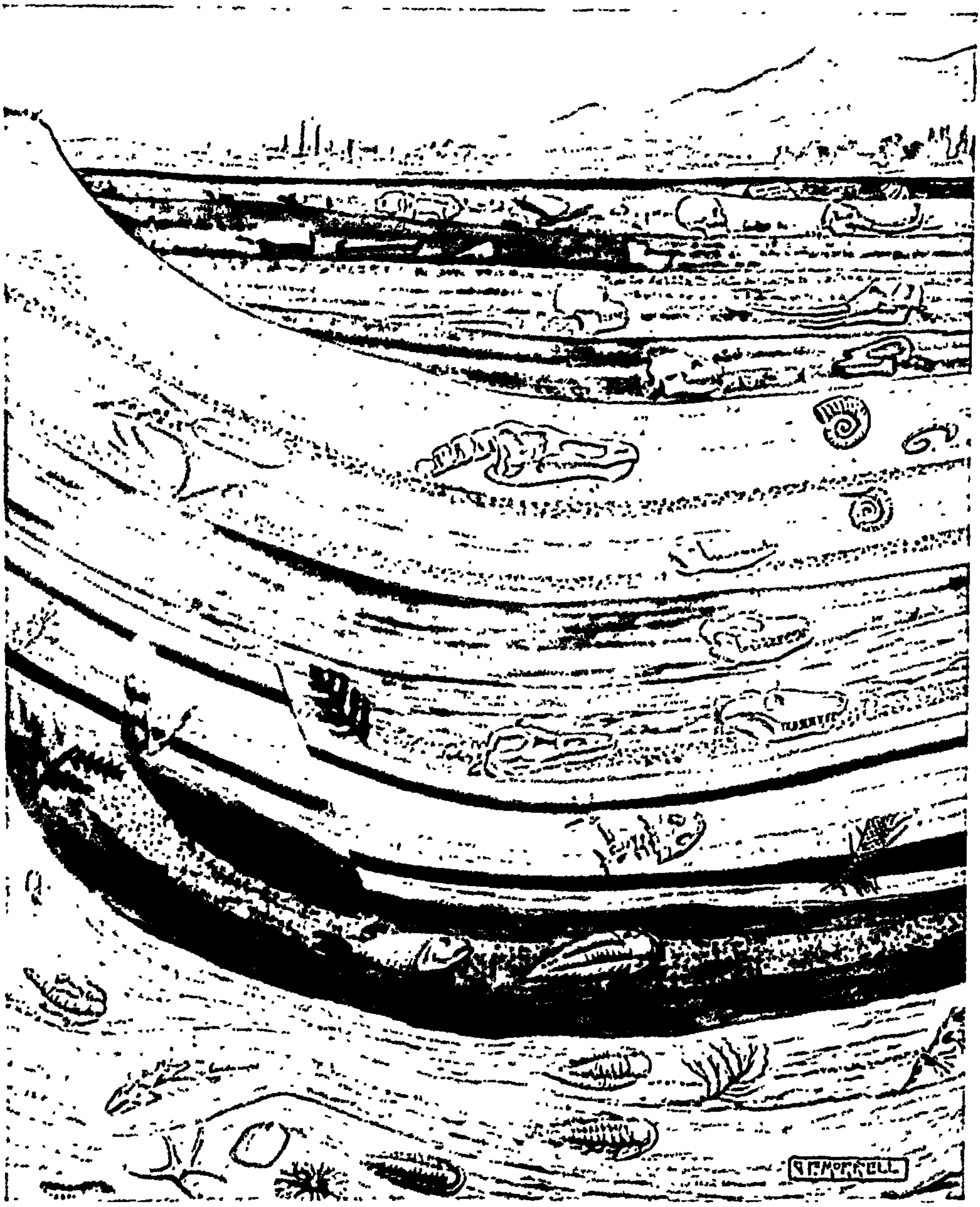
The Early Reptiles.

It is a suggestive fact that the embryos of all reptiles, birds, and mammals show gill-clefts —*a tell-tale evidence of their distant aquatic ancestry*. But these embryonic gill-clefts are not used for respiration and show no trace of gills except in a few embryonic reptiles and birds where their dwindled vestiges have been recently discovered. As to the gill-clefts, they are of no use in higher Vertebrates except that the first becomes the Eustachian tube leading from the ear-passage to the back of the mouth. The reason why they persist when only one is of any use, and that in a transformed guise, would be difficult to interpret except in terms of the Evolution theory. They illustrate the lingering influence of a long pedigree, the living hand of the past, the tendency that individual development has to recapitulate racial evolution. In a condensed and telescoped manner, of course, for what took the race a million years may be recapitulated by the individual in a week!

In the Permian period the warm moist climate of most of the Carboniferous period was replaced by severe conditions, culminating in an Ice Age which spread from the Southern Hemisphere throughout the world. With this was associated a waning of the Carboniferous flora, and the appearance of a new one, consisting of ferns, conifers, ginkgos, and cycads, which persisted until near the end of the Mesozoic era. The Permian Ice Age lasted for millions of years, and was most severe in the Far South. Of course, it was a very different world then, for North Europe was joined to North America, Africa to South America, and Australia to Asia. It was probably during the Permian Ice Age that many of the insects divided their life-history into two main chapters—the feeding, growing, moulting, immature, larval stages, e.g. caterpillars, and the more ascetic, non-growing, non-moulting, winged phase, adapted for reproduction. Between these there intervened the quiescent, well-protected pupa stage or chrysalis, probably adapted to begin with as a means of surviving the severe winter. For it is easier for an animal to survive when the vital processes are more or less in abeyance.

We cannot leave the last period of the Palæozoic era and its prolonged ice age without noticing that it meant the entire cessation of a large number of ancient types, especially among plants and backboneless animals, which now disappear for ever. It is necessary to understand that the animals of ancient days stand in three different relations to those of to-day. (*a*) There are ancient types that have living representatives, sometimes few and sometimes many, sometimes

Disappearance of many Ancient Types.



PICTORIAL REPRESENTATION OF THE SUCCESSIVE STRATA OF THE EARTH'S CRUST, WITH SUGGESTIONS OF CHARACTERISTIC FOSSILS.

E.g. Fish and Trilobite in the Devonian (red), a large Amphibian in the Carboniferous (blue), Reptiles in Permian *(light red), the first Mammal in the Triassic (blue), the first bird in the Jurassic (yellow), Giant Reptiles in the* Cretaceous (white), then follow the Tertiary strata with progressive mammals, and Quaternary at the top with man and mammoth.

much changed and sometimes but slightly changed. The lamp-shell, *Lingulella*, of the Cambrian and Ordovician period has a very near relative in the *Lingula* of to-day. There are a few extremely conservative animals. (*b*) There are ancient types which have no living representatives, except in the guise of transformed descendants, as the King-crab (*Limulus*) may be said to be a transformed descendant of the otherwise quite extinct race to which Eurypterids or Sea-scorpions belonged. (*c*) There are altogether extinct types—*lost races*—which have left not a wrack behind. For there is not any representation to-day of such races as Graptolites and Trilobites.

Looking backwards over the many millions of years comprised in the Palæozoic era, what may we emphasise as the most salient features? There was in the *Cambrian* the establishment of the chief classes of backboneless animals: in the *Ordovician* the first fishes and perhaps the first terrestrial plants; in the *Silurian* the emergence of air-breathing Invertebrates and mud-fishes: in the *Devonian* the appearance of the first Amphibians, from which all higher land animals are descended, and the establishment of a land flora; in the *Carboniferous* the great Club-moss forests and an exuberance of air-breathing insects and their allies; in the *Permian* the first reptiles and a new flora.

THE GEOLOGICAL MIDDLE AGES

§ 1

The Mesozoic Era.

In a broad way the Mesozoic era corresponds with the Golden Age of reptiles, and with the climax of the Conifer and Cycad flora, which was established in the Permian. But among the Conifers and Cycads our modern flowering plants were beginning to show face tentatively, just like birds and mammals among the great reptiles.

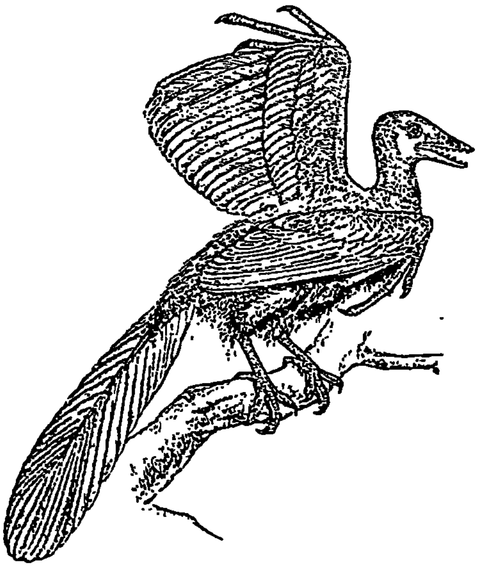
In the *Triassic* period the exuberance of reptilian life which marked the Permian was continued. Besides Turtles which still persist, there were Ichthyosaurs, Plesiosaurs, Dinosaurs, and Pterosaurs, none of which lasted beyond the Mesozoic era. Of great importance was the rise of the Dinosaurs in the Triassic, for it is highly probable that within the limits of this vigorous and plastic stock—some of them bipeds—we must look for the ancestors of both birds and mammals. Both land and water were dominated by reptiles, some of which attained to gigantic size. Had there been any zoologist in those days, he would have been very sagacious indeed if he had suspected that reptiles did not represent the climax of creation.

The Flying Dragons.

The *Jurassic* period showed a continuance of the reptilian splendour. They radiated in many directions, becoming adapted to many haunts. Thus there were many Fish Lizards paddling in the seas, many types of terrestrial dragons stalking about on land, many swiftly gliding alligator-like forms, and the Flying Dragons which began in the Triassic attained to remarkable success and variety. Their wing was formed by the extension of a great fold of skin on the enormously elongated outermost finger, and they varied from the size of a sparrow to a spread of over five feet. A soldering of the dorsal vertebræ as in our Flying Birds was an adaptation to striking the air with some force, but as there is not more than a slight keel, if any, on the breast-bone, it is unlikely that they could fly far. For we know from our modern birds that the power of flight may be to some extent gauged from the degree of development of the keel, which is simply a great ridge for the better insertion of the muscles of flight. It is absent, of course, in the Running Birds, like the ostrich, and it has degenerated in an interesting way in the burrowing parrot (*Stringops*) and a few other birds that have "gone back."

The First Known Bird.

But the Jurassic is particularly memorable because its strata have yielded two fine specimens of the first known bird, *Archæopteryx*. These were entombed in the deposits which formed the fine-grained lithographic stones of Bavaria, and practically every bone in the body is preserved except the breast-bone. Even the feathers have left their marks with distinctness. This oldest known bird—too far advanced to be



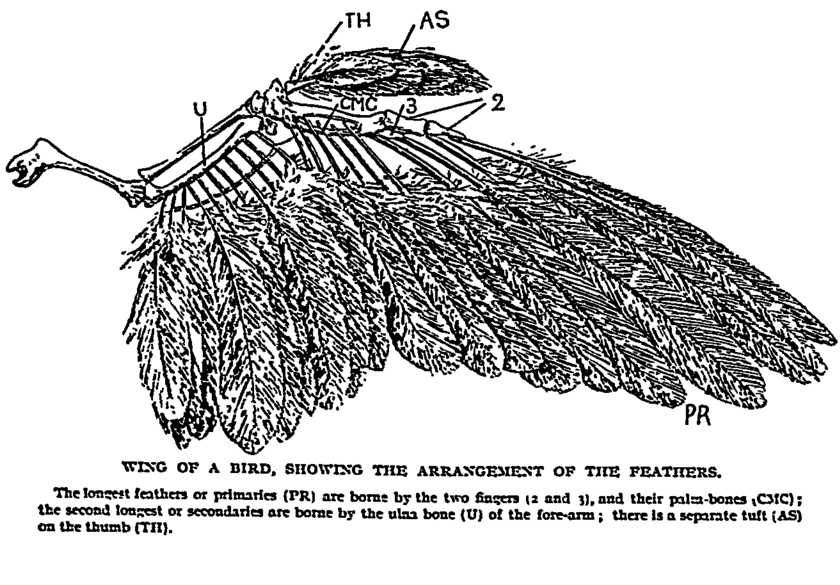
THE ARCHÆOPTERYX.

(After William Lecke of Stockholm.)

A good restoration of the oldest known bird, Archæopteryx (Jurassic Era). It was about the size of a crow; it had teeth on both jaws; it had claws on the thumb and two fingers; and it had a long lizard-like tail. But it had feathers, proving itself a true bird.

the first bird—was about the size of a crow and was probably of arboreal habits. Of great interest are its reptilian features, so pronounced that one cannot evade the evolutionist suggestion. It had teeth in both jaws, which no modern bird has; it had a long lizard-like tail, which no modern bird has; it had claws on three fingers, and a sort of half-made wing. That is to say, it does not show, what all modern birds show, a fusion of half the wrist-bones with the whole of the palm-bones, the well-known carpo-metacarpus bone which forms a basis for the longest pinions. In many reptiles, such as Crocodiles, there are peculiar bones running across the abdomen beneath the skin, the so-called "abdominal ribs," and it seems an eloquent detail to find these represented in *Archæopteryx*, the earliest known bird. No modern bird shows any trace of them.

There is no warrant for supposing that the flying reptiles or Pterodactyls gave rise to birds, for the two groups are on different lines, and the structure of the wings is entirely different. Thus the long-fingered Pterodactyl wing was a parachute wing, while the secret of the bird's wing has its centre in the feathers. It is highly probable that birds evolved from certain Dinosaurs which had become bipeds, and it is possible that they were for a time swift runners that took "flying jumps" along the ground. Thereafter, perhaps, came a period of arboreal apprenticeship during which there was much gliding from tree to tree before true flight was achieved. It is an interesting fact that the



WING OF A BIRD, SHOWING THE ARRANGEMENT OF THE FEATHERS.

The longest feathers or primaries (PR) are borne by the two fingers (2 and 3), and their palm-bones (CMC); the second longest or secondaries are borne by the ulna bone (U) of the fore-arm; there is a separate tuft (AS) on the thumb (TH).

problem of flight has been solved four times among animals—by insects, by *Pterodactyls*, by birds, and by bats; and that the four solutions are on entirely different lines.

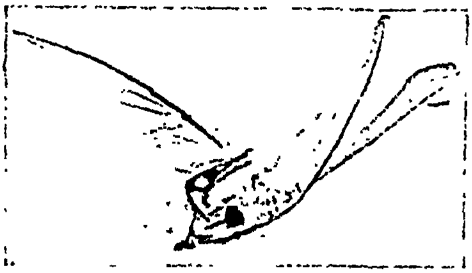


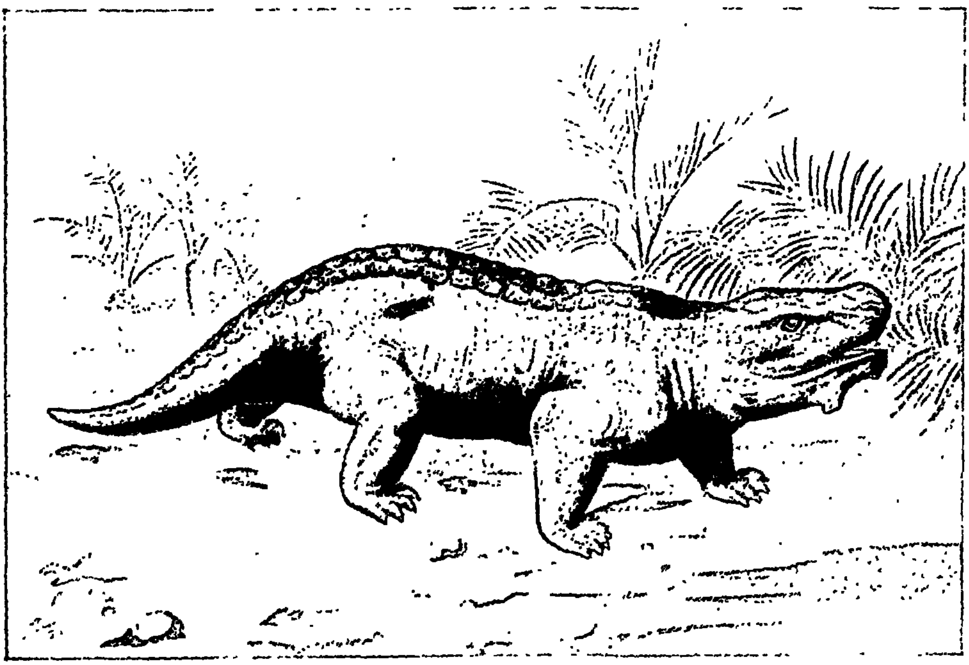
Photo: British Museum (Natural History).

FOSSIL OF A PTERODACTYL OR EXTINCT FLYING DRAGON.

The wing is made of a web of skin extended on the enormously elongated outermost finger. The long tail served for balancing and steering. The Pterodactyls varied from the size of sparrows to a wing span of fifteen feet—the largest flying creatures.

In the *Cretaceous* period the outstanding events included the waning of giant reptiles, the modernising of the flowering plants, and the multiplication of small mammals. Some of the Permian reptiles, such as the dog-toothed Cynodonts, were extraordinarily mammal-like, and it was probably from among them that definite mammals emerged in the Triassic. Comparatively little is known of the early Triassic mammals save that their back-teeth were marked by numerous tubercles on the crown, but they were gaining strength in the late Triassic when small arboreal insectivores, not very distant from the modern tree-shrews (*Tupaia*), began to branch out in many directions indicative of the great divisions of modern mammals, such as the clawed mammals, hoofed mammals, and the race of monkeys or Primates. In the Upper Cretaceous there was an exuberant "radiation" of mammals, adaptive to the conquest of all sorts of haunts, and this was vigorously continued in Tertiary times.

There is no difficulty in the fact that the earliest remains of definite mammals in the Triassic precede the first-known bird in the Jurassic. For although we usually rank mam-



From Knipe's "Nebula to Man."

PARIASAURUS: AN EXTINCT VEGETARIAN TRIASSIC REPTILE.

Total length about 9 feet. (Remains found in Cape Colony, South Africa.)

mals as higher than birds (being mammals ourselves, how could we do otherwise?), there are many ways in which birds are pre-eminent, e.g. in skeleton, musculature, integumentary structures, and respiratory system. The fact is that birds and mammals are on two quite different tacks of evolution, not related to one another, save in having a common ancestry in extinct reptiles. Moreover, there is no reason to believe that the Jurassic *Archæopteryx* was the first bird in any sense except that it is the first of which we have any record. In any case it is safe to say that birds came to their own before mammals did.

Looking backwards, we may perhaps sum up what is most essential in the Mesozoic era in Professor Schuchert's sentence: "The Mesozoic is the Age of Reptiles, and yet the little mammals and the toothed birds are storing up intelligence and strength to replace the reptiles when the cycads and conifers shall give way to the higher flowering plants."

§ 2

The Cenozoic or Tertiary Era.

In the *Eocene* period there was a replacement of the small-brained archaic mammals by big-brained modernised types, and with this must be associated the covering of the earth with a garment of grass and dry pasture. Marshes were replaced by meadows and browsing by grazing mammals. In the spreading meadows an opportunity was also offered for a richer evolution of insects and birds.

During the *Oligocene* the elevation of the land continued, the climate became much less moist, and the grazing herds extended their range.

The *Miocene* was the mammalian Golden Age, and there were crowning examples of what Osborn calls "adaptive radiation." That is to say, mammals, like the reptiles before them, conquer every haunt of life. There are flying bats, volplaning parachutists, climbers in trees like sloths and squirrels, quickly moving hoofed mammals, burrowers like the moles, freshwater mammals, like duckmole and beaver, shore-frequenting seals and manatees, and open-sea cetaceans, some of which dive far more than full fathoms five. It is important to realise the perennial tendency of animals to conquer every corner and to fill every niche of opportunity, and to notice that this has been done by successive sets of animals in succeeding ages. *Most notably the mammals repeat all the experiments of reptiles on a higher turn of the spiral.* Thus arises what is called convergence, the superficial resemblance of unrelated types, like whales and fishes, the resemblance being due to the fact that the different types are similarly adapted to similar conditions of life. Professor H. F. Osborn points out that mammals may seek any one of the twelve different habitat-zones, and that in each of these there may be six quite different kinds of food. Living creatures penetrate everywhere like the overflowing waters of a great river in flood.

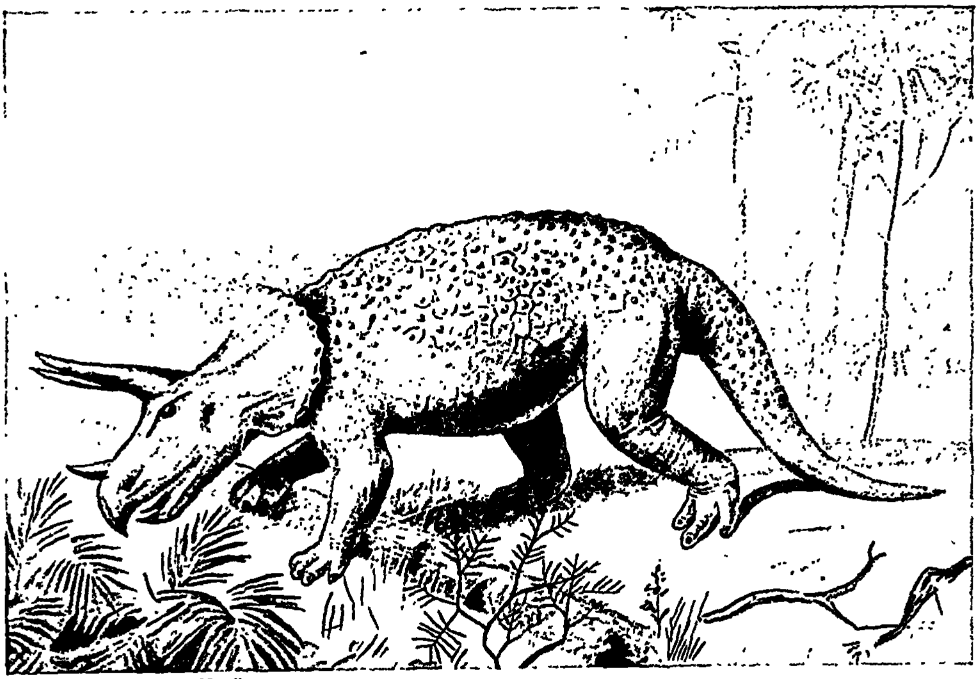
§ 3

The *Pliocene* period was a more strenuous time, with less genial climatic conditions, and with more intense competition. Old land bridges were broken and new ones made, and the geographical distribution underwent great changes. Professor R. S. Lull describes the *Pliocene* as "a period of great unrest." "Many migrations occurred the world over, new competitions arose, and the weaker stocks began to show the effects of the strenuous life. One momentous event seems to have occurred in the Pliocene, and that was the transformation of the precursor of humanity into man—the culmination of the highest line of evolution."

The *Pleistocene* period was a time of sifting. There was a continued elevation of the continental masses, and Ice Ages set in, relieved by less severe interglacial times when the ice-sheets retreated northwards for a time. Many types, like the mammoth, the woolly rhinoceros, the sabre-toothed tiger, the cave-lion, and the cave-bear, became extinct. Others which formerly had a wide range became restricted to the Far North or were left isolated here and there on the high mountains, like the Snow Mouse, which now occurs on isolated Alpine heights above the snow-line. Perhaps it was during this period that many birds of the Northern Hemisphere learned to evade the winter by the sublime device of migration.

Looking backwards we may quote Professor Schuchert again: "The lands in the Cenozoic begin to bloom with more and more flowering plants and grand hardwood forests, the atmo-

sphere is scented with sweet odours, a vast crowd of new kinds of insects appear, and the places of the once dominant reptiles of the lands and seas are taken by the mammals. Out of these struggles there rises a greater intelligence, seen in nearly all of the mammal stocks, but particularly in one, the monkey-ape-man line. Brute man appears on the scene with the introduction of the last glacial climate, a most trying time for all things endowed with life, and finally there results the dominance of reasoning man over all his brute associates." In man and human society the story of evolution has its climax.



From Knipe's "Nebula to Man."

TRICERATOPS: A HUGE EXTINCT REPTILE.

(From remains found in Cretaceous strata of Wyoming, U.S.A.)

This Dinosaur, about the size of a large rhinoceros, had a huge three-horned skull with a remarkable bony collar over the neck. But, as in many other cases, its brain was so small that it could have passed down the spinal canal in which the spinal cord lies. Perhaps this partly accounts for the extinction of giant reptiles.

The Ascent of Man.

Man stands apart from animals in his power of building up general ideas and of using these in the guidance of his behaviour and the control of his conduct. This is essentially wrapped up with his development of language as an instrument of thought. Some animals have words, but man has language (Logos). Some animals show evidence of *perceptual* inference, but man often gets beyond this to *conceptual* inference (Reason). Many animals are affectionate and brave, self-forgetful and industrious, but man " thinks the ought," definitely guiding his conduct in the light of ideals, which in turn are wrapped up with the fact that he is " a social person."

Besides his big brain, which may be three times as heavy as that of a gorilla, Man has various physical peculiarities. He walks erect, he plants the sole of his foot flat on the ground, he has a chin and a good heel, a big forehead and a non-protrusive face, a relatively uniform set of teeth without conspicuous canines, and a relatively naked body.

But in spite of Man's undeniable apartness, there is no doubt as to his solidarity with the rest of creation. There is an " all-pervading similitude of structure " between man and the Anthropoid Apes, though it is certain that it is not from any living form that he took his origin.

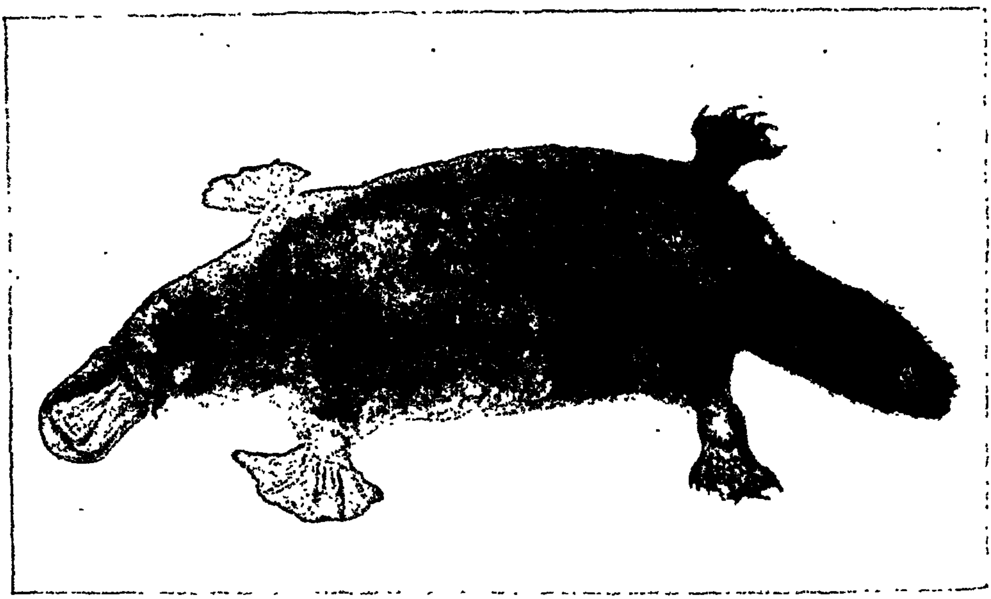


Photo: "Daily Mail."

THE DUCKMOLE OR DUCK-BILLED PLATYPUS OF AUSTRALIA.

The Duckmole or Duck-billed Platypus of Australia is a survivor of the most primitive mammals. It harks back to reptiles, e.g. in being an egg layer, in having comparatively large eggs, and in being imperfectly warm-blooded. It swims well and feeds on small water-animals. It can also burrow.

None of the anatomical distinctions, except the heavy brain could be called momentous. Man's body is a veritable museum of relics (vestigial structures) inherited from pre-human ancestors. In his everyday bodily life and in some of its disturbances, man's pedigree is often revealed. Even his facial expression, as Darwin showed, is not always human. Some fossil remains bring modern man nearer the anthropoid type.

It is difficult not to admit the ring of truth in the closing words of Darwin's *Descent of Man*: "We must, however, acknowledge, as it seems to me, that man, with all his noble qualities, with sympathy which feels for the most debased, with benevolence which extends not only to other men but to the humblest living creature, with his God-like intellect which has penetrated into the movements and constitution of the solar system—with all these exalted powers—man still bears in his bodily frame the indelible stamp of his lowly origin."

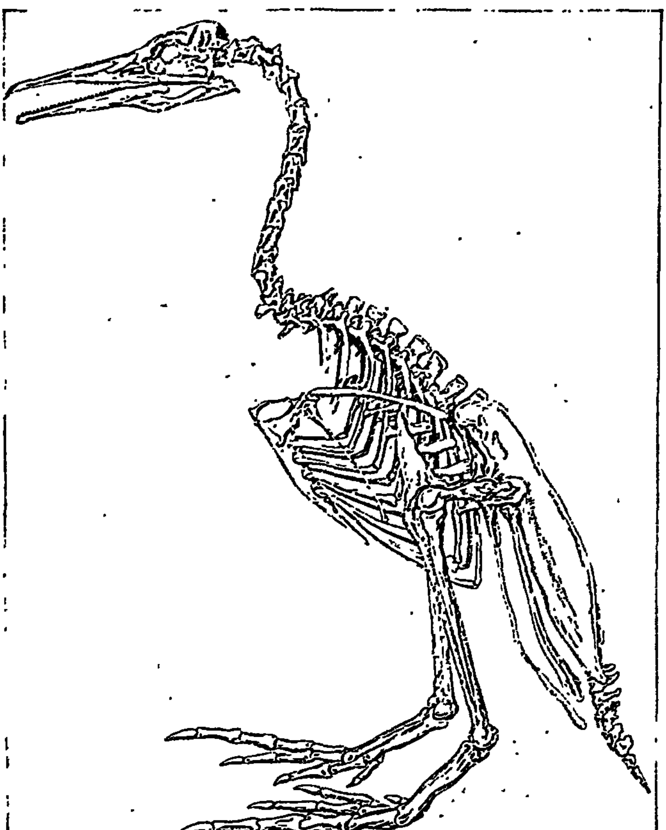
The Evolving System of Nature

There is another side of evolution so obvious that it is often overlooked, the tendency to link lives together in vital inter-relations. Thus flowers and their insect visitors are often vitally interlinked in mutual dependence. Many birds feed on berries and distribute the seeds. The tiny freshwater snail is the host of the juvenile stages of the liver-fluke of the sheep. The mosquito is the vehicle of malaria from man to man, and the tse-tse fly spreads sleeping sickness. The freshwater mussel cannot continue its race without the unconscious co-operation of the minnow, and the freshwater fish called the bitterling cannot continue its race without the unconscious co-operation of the mussel. There are numerous mutually beneficial partnerships between different kinds of creatures, and other inter-relations where the benefit is one-sided, as in the case of insects that make galls on plants. There are also among kindred animals many forms of colonies, communities, and societies. Nutritive chains bind long series of animals together, the cod feeding on the whelk, the whelk on the worm, the worm on the organic dust of the sea. There is a system of successive incarnations and matter is continually passing from one embodiment to another. These instances must

suffice to illustrate the central biological idea of the web of life, the interlinked System of Animate Nature. Linnæus spoke of the Systema Naturæ, meaning the orderly hierarchy of classes, orders, families, genera, and species; but we owe to Darwin in particular some knowledge of a more dynamic Systema Naturæ, the network of vital inter-relations. This has become more and more complex as evolution has continued, and man's web is most complex of all. It means making Animate Nature more of a unity; it means an external method of registering steps of progress; it means an evolving set of sieves by which new variations are sifted, and living creatures are kept from slipping down the steep ladder of evolution.

Parasitism.

It sometimes happens that the inter-relation established between one living creature and another works in a retrograde direction. This is the case with many thoroughgoing internal parasites which have sunk into an easygoing kind of life, utterly dependent on their host for food, requiring no exertions, running no risks, and receiving no spur to effort. Thus we see that evolution is not necessarily progressive; everything



SKELETON OF AN EXTINCT FLIGHTLESS TOOTHED BIRD, HESPERORNIS.

(After Marsh.)

The bird was five or six feet high, something like a swimming ostrich, with a very powerful leg but only a vestige of a wing. There were sharp teeth in a groove. The modern divers come nearest to this ancient type.

depends on the conditions in reference to which the living creatures have been evolved. When the conditions are too easygoing, the animal may be thoroughly well adapted to them—as a tapeworm certainly is—but it slips down the rungs of the ladder of evolution.

This is an interesting minor chapter in the story of evolution—the establishment of different kinds of parasites, casual and constant, temporary and lifelong, external hangers-on and internal unpaying boarders, those that live in the food-canal and depend on the host's food and those that inhabit the blood or the tissues and find their food there. It seems clear that ichneumon grubs and the like which hatch inside a caterpillar and eat it alive are not so much parasites as "beasts of prey" working from within.

But there are two sides to this minor chapter: there is the evolution of the parasite, and there is also the evolution of counteractive measures on the part of the host. Thus there is the maintenance of a bodyguard of wandering amœboid cells, which tackle the microbes invading the body and often succeed in overpowering and digesting them. Thus, again, there is the protective capacity the blood has of making antagonistic substances or "anti-bodies" which counteract poisons, including the poisons which the intruding parasites often make.

THE EVIDENCES OF EVOLUTION—HOW IT CAME ABOUT

§ 1

Progress in Evolution.

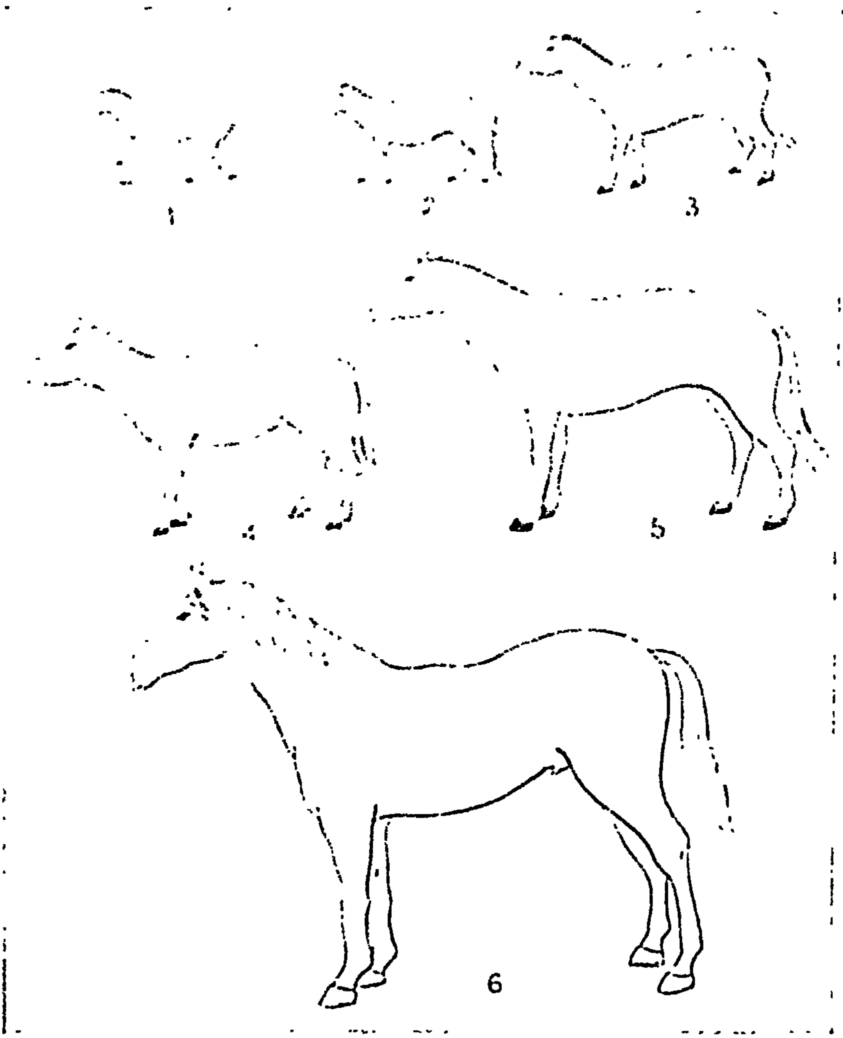
There has often been slipping back and degeneracy in the course of evolution, but the big fact is that there has been progress. For millions of years Life has been slowly creeping upwards, and if we compare the highest animals—Birds and Mammals—with their predecessors, we must admit that they are more controlled, more masters of their fate, with more mentality. Evolution is on the whole *integrative*; that is to say, it makes against instability and disorder, and towards harmony and progress. Even in the rise of Birds and Mammals we can discern that the evolutionary process was making towards a fuller embodiment or expression of what Man values most—control, freedom, understanding, and love. The advance of animal life through the ages has been chequered, but on the whole it has been an advance towards increasing fullness, freedom, and fitness of life. In the study of this advance—the central fact of Organic Evolution—there is assuredly much for Man's instruction and much for his encouragement.

Evidences of Evolution.

In all this, it may be said, the fact of evolution has been taken for granted, but what are the evidences? Perhaps it should be frankly answered that the idea of evolution, that the present is the child of the past and the parent of the future, cannot be *proved* as one may prove the Law of Gravitation. All that can be done is to show that it is a key—a way of looking at things—that fits the facts. There is no lock that it does not open.

But if the facts that the evolution theory vividly interprets be called the evidences of its validity, there is no lack of them. There is *historical* evidence; and what is more eloquent than the general fact that fishes emerge before amphibians, and these before reptiles, and these before birds, and so on? There are wonderfully complete fossil series, e.g. among cuttlefishes, in which we can almost see evolution in process. The pedigree of horse and elephant and crocodile is in general very convincing, though it is to be confessed that there are other cases in regard to which we have no light. Who can tell, for instance, how Vertebrates arose or from what origin?

There is *embryological* evidence, for the individual development often reads like an abbreviated recapitulation of the presumed evolution of the race. The mammal's visceral clefts are tell-tale evidences of remote aquatic ancestors, breathing by gills. Something is known in regard to the historical evolution of antlers in bygone ages; the Red Deer of to-day recapitulates at least the general outlines of the history. The individual development of an



SIX STAGES IN THE EVOLUTION OF THE HORSE, SHOWING GRADUAL INCREASE IN SIZE.

(After Lull and Matthew.)

1. Four-toed Horse, Eohippus, about one foot high. Lower Eocene, N. America.
2. Another four-toed Horse, Orohippus, a little over a foot high. Middle Eocene, N. America.
3. Three-toed Horse, Mesohippus, about the size of a sheep. Middle Oligocene, N. America.
4. Three-toed Horse, Merychippus, Miocene, N. America. Only one toe touches the ground on each foot, but the remains of two others are prominent.
5. The first one-toed Horse, Pliohippus, about forty inches high at the shoulder. Pliocene, N. America.
6. The modern horse, standing on the third digit of each foot.

asymmetrical flat-fish, like a plaice or sole, which rests and swims on one side, tells us plainly that its ancestors were symmetrical fishes.

There is what might be called *physiological* evidence, for many plants and animals are variable before our eyes, and evolution is going on around us to-day. This is familiarly seen among domesticated animals and cultivated plants, but there is abundant flux in Wild Nature. It need hardly be said that some organisms are very conservative, and that change need not be expected when a position of stable equilibrium has been secured.

There is also *anatomical* evidence of a most convincing quality. In the fore-limbs of back-boned animals, say, the paddle of a turtle, the wing of a bird, the flipper of a whale, the foreleg of a horse, and the arm of a man; the same essential bones and muscles are used to such diverse results! What could it mean save blood relationship? And as to the two sets of teeth in whalebone whales, which never even cut the gum, is there any alternative but to regard them as relics of useful teeth which ancestral forms possessed? In short, the evolution theory is justified by the way in which it works.

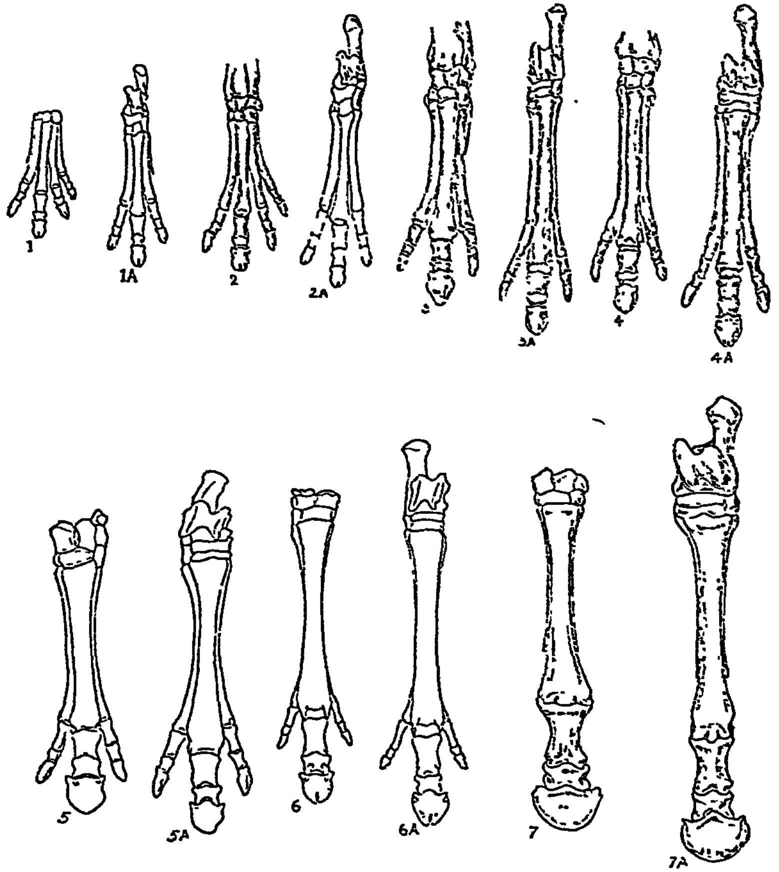
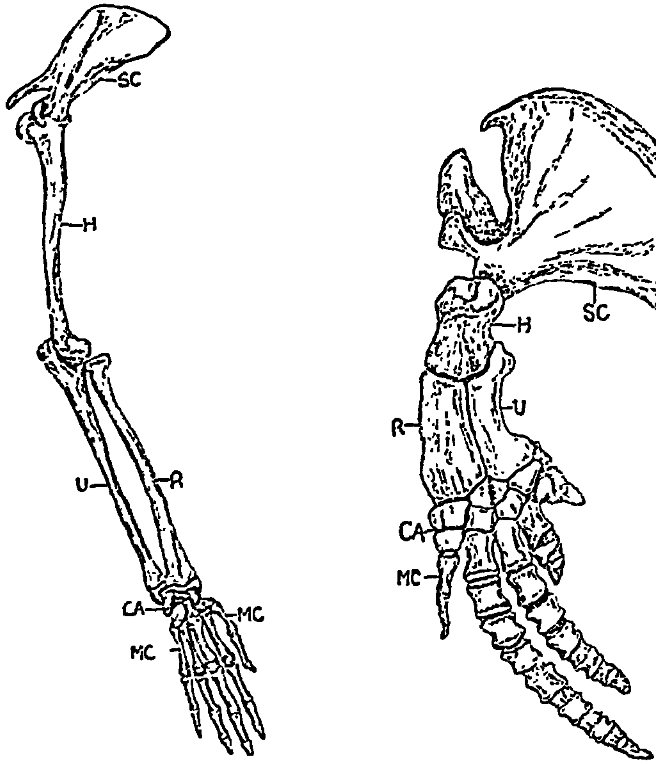


DIAGRAM SHOWING SEVEN STAGES IN THE EVOLUTION OF THE FORE-LIMBS AND HIND-LIMBS OF THE ANCESTORS OF THE MODERN HORSE, BEGINNING WITH THE EARLIEST KNOWN PREDECESSORS OF THE HORSE AND CULMINATING WITH THE HORSE OF TO-DAY.

(*After Marsh and Lull.*)

1 and 1A, fore-limb and hind-limb of Eohippus; 2 and 2A, Orohippus; 3 and 3A, Mesohippus; 4 and 4A, Hypohippus; 5 and 5A, Merychippus; 6 and 6A, Hipparion, 7 and 7A, the modern horse. Note how the toes shorten and disappear.



A. Fore-limb of Monkey. B. Fore-limb of Whale.

WHAT IS MEANT BY HOMOLOGY? ESSENTIAL SIMILARITY OF ARCHITECTURE, THOUGH THE APPEARANCES MAY BE VERY DIFFERENT.

This is seen in comparing these two fore limbs, A, of Monkey, B of Whale. They are as different as possible, yet they show the same bones, e.g. SC, the scapula or shoulder-blade; H, the humerus or upper arm; R and U, the radius and ulna of the fore-arm; CA, the wrist; MC, the palm; and then the fingers.

§ 2

Factors in Evolution.

If it be said "So much for the *fact* of evolution, but what of the *factors*?" the answer is not easy. For not only is the problem the greatest of all scientific problems, but the inquiry is still very young. The scientific study of evolution practically dates from the publication of *The Origin of Species* in 1859.

Heritable novelties or variations often crop up in living creatures, and these form the raw material of evolution. These variations are the outcome of expression of changes in the germ-cells that develop into organisms. But why should there be changes in the constitution of the germ-cells? Perhaps because the living material is very complex and inherently liable to change; perhaps because it is the vehicle of a multitude of hereditary items among which there are very likely to be reshufflings or rearrangements; perhaps because the germ-cells have very changeful surroundings (the blood, the body-cavity fluid, the sea-water); perhaps because deeply saturating outside influences, such as change of climate and habitat, penetrate through the body to its germ-cells and provoke them to vary. But we must be patient with the wearisome reiteration of "perhaps." Moreover, every many-celled organism, reproduced in the usual way, arises from an egg-cell fertilised by a sperm-cell, and the changes involved in and preparatory to this fertilisation may make new permutations and combinations of the living items and hereditary qualities not only possible but necessary. It is something like

shuffling a pack of cards, but the cards are living. As to the changes wrought on the body during its lifetime by peculiarities in nurture, habits, and surroundings, these dents or modifications are often very important for the individual, but it does not follow that they are directly important for the race, since it is not certain that they are transmissible.

Given a crop of variations or new departures or mutations, whatever the inborn novelties may be called, we have then to inquire how these are sifted. The sifting, which means the elimination of the relatively less fit variations and the selection of the relatively more fit, is effected in many different ways in the course of the struggle for existence. The organism plays its new card in the game of life, and the consequences may determine survival. The relatively less fit to given conditions will tend to be eliminated, while the relatively more fit will tend to survive. If the variations are hereditary and reappear, perhaps increased in amount, generation after generation, and if the process of sifting continue consistently, the result will be the evolution of the species. The sifting process may be helped by various forms of "isolation" which lessen the range of free intercrossing between members of a species, e.g. by geographical barriers. Interbreeding of similar forms tends to make a stable stock; outbreeding among dissimilars tends to promote variability. But for an outline like this it is enough to suggest the general method of organic evolution: Throughout the ages organisms have been making tentatives—new departures of varying magnitude—and these tentatives have been tested. The method is that of testing all things and holding fast that which is good.

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THE ROMANCE OF THE HEAVENS

(*Continued from page 24*)

THE NEBULAR THEORY

§ 2

Nebulæ are dim luminous cloud-like patches in the heavens, more like wisps of smoke in some cases than anything else. Both photography and the telescope show that they are very numerous, hundreds of thousands being already known and the number being continually added to. They are not small. Most of them are immensely large. Actual dimensions cannot be given, because to estimate these we must first know definitely the distance of the nebulæ from the earth. The distances of some nebulæ are known approximately, and we can therefore form some idea of size in these cases. The results are staggering. The mere visible surface of some nebulæ is so large that the whole stretch of the solar system would be too small to form a convenient unit for measuring it. A ray of light would require to travel for years to cross from side to side of such a nebula. Its immensity is inconceivable to the human mind.

There appear to be two types of nebulæ, and there is evidence suggesting that the one type is only an earlier form of the other; but this again we do not know.

The more primitive nebulæ would seem to be composed of gas in an extremely rarefied form. It is difficult to convey an adequate idea of the rarity of nebular gases. The residual gases in a vacuum tube are dense by comparison A cubic inch of air at ordinary pressure would contain more matter than is contained in millions of cubic inches of the gases of nebulæ. The light of even the faintest stars does not seem to be dimmed by passing through a gaseous nebula, although we cannot be sure on this point. The most remarkable physical fact about these gases is that they are luminous. Whence they derive their luminosity we do not know. It hardly seems possible to believe that extremely thin gases exposed to the terrific cold of space can be so hot as to be luminous and can retain their heat and their luminosity indefinitely. A cold luminosity due to electrification, like that of the aurora borealis, would seem to fit the case better.

Now the nebular theory is that out of great "fire-mists," such as we have described, stars are born. We do not know whether gravitation is the only or even the main force at work in a nebula, but it is supposed that under the action of gravity the far-flung "fire-mists" would begin to condense round centres of greatest density, heat being evolved in the process. Of course the condensation would be enormously slow, although the sudden irruption of a swarm of meteors or some solid body might hasten matters greatly by providing large, ready-made centres of condensation.

Spiral Nebulæ.

It is then supposed that the contracting mass of gas would begin to rotate and to throw off gigantic streamers, which would in their turn form centres of condensation. The whole structure would thus form a spiral, having a dense region at its centre and knots or lumps of condensed matter along its spiral arms. Besides the formless gaseous nebulæ there are hundreds of thousands of "spiral" nebulæ such as we have just mentioned in the heavens. They are at all stages of development, and they are visible to us at all angles—that is to say, some of them face directly towards us, others are edge on, and some are in intermediate positions. It appears, therefore, that we have here a striking confirmation of the nebular hypothesis. But we must not go so fast. There is much controversy as to the nature of these spiral nebulæ. Some eminent astronomers think they are other stellar universes, comparable in size with our own. In any case they are vast structures, and if they represent stars in process of condensation, they must be giving birth to huge agglomerations of stars—to star clusters at least. These vast and enigmatic objects do not throw much light on the origin of our own solar system. The nebular hypothesis, which was invented by Laplace to explain the origin of our solar system, has not met with universal acceptance. The explanation offers grave difficulties, and it is best, while

the subject is still being closely investigated, to hold all opinions with reserve. It may be taken as probable, however, that the universe has developed from masses of incandescent gas.

THE BIRTH AND DEATH OF STARS

§ 3

Variable, New, and Dark Stars: Dying Suns.

Many astronomers believe that in "variable stars" we have another star, following that of the dullest red star, in the dying of suns. The light of these stars varies periodically in so many days, weeks, or years. It is interesting to speculate that they are slowly dying suns, in which the molten interior periodically bursts through the shell of thick vapours that is gathering round them. What we saw about our sun seems to point to some such stage in the future. That is, however, not the received opinion about variable stars. It may be that they are stars which periodically pass through a great swarm of meteors or a region of space that is rich in cosmic dust of some sort, when, of course, a great illumination would take place.

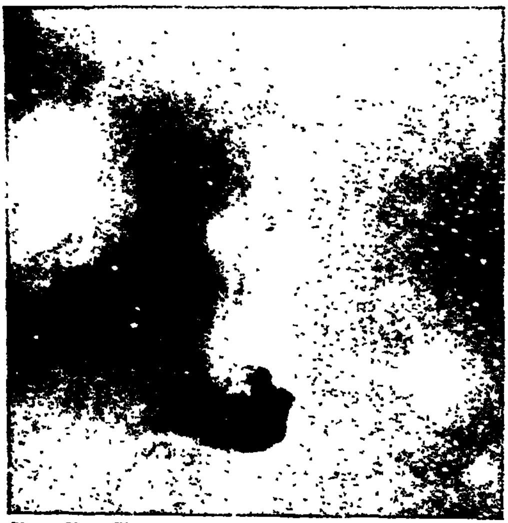


Photo: Mount Wilson Observatory.

FIG. 24.—A NEBULAR REGION SOUTH OF ZETA ORIONIS.

Showing a great projection of "dark matter" cutting off the light from behind.

One class of these variable stars which takes its name from the star Algol, is of special interest. Every third night Algol has its light reduced for several hours. Modern astronomy has discovered that in this case there are really two stars, circulating round a common centre, and that every third night the fainter of the two comes directly between us and its companion and causes an "eclipse." This was until recently regarded as a most interesting case in which a dead star revealed itself to us by passing before the light of another star. But astronomers have in recent years invented something, the "selenium-cell," which is even more sensitive than the photographic plate, and on this the supposed dead star registers itself as very much alive. Algol is, however, interesting in another way. The pair of stars which we have discovered in it are hundreds of billions of miles away from the earth, yet we know their masses and their distances from each other.

The Death and Birth of Stars.

We have no positive knowledge of dead stars; which is not surprising when we reflect that a dead star means an invisible star! But when we see so many individual stars tending toward death, when we behold a vast population of all conceivable ages, we presume that there are many already dead. On the other hand, there is no reason to suppose that the universe as a whole is "running down." Some writers have maintained this, but their argument implies that we know a great deal more about the universe than we actually do. The scientific man does not know whether the universe is finite or infinite, temporal or eternal; and he declines to speculate where there are no facts to guide him. He knows only that the great gaseous nebulæ promise myriads of worlds in the future, and he concedes the possibility that new nebulæ may be forming in the ether of space.

The last, and not the least interesting, subject we have to notice is the birth of a "new star." This is an event which astronomers now announce every few years; and it is a far more portentous event than the reader imagines when it is reported in his daily paper. The story is much the same in all cases. We say that the star appeared in 1901, but you begin to realise the magnitude of the event when you learn that

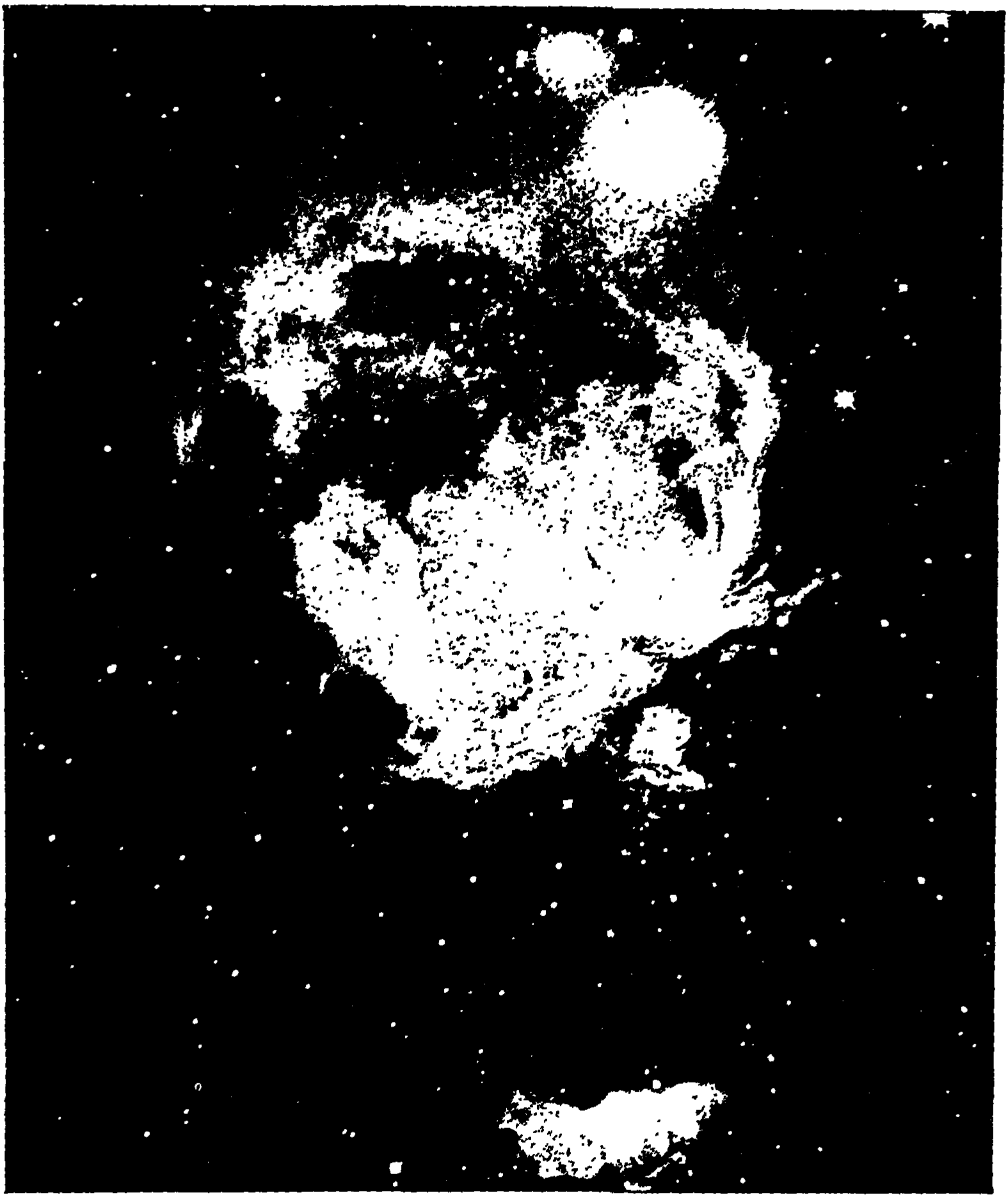


Photo: Yerkes Observatory.

FIG. 23.—THE GREAT NEBULA IN ORION.

The most impressive nebula in the heavens. It is inconceivably greater in dimensions than the whole solar system.

the distant "blaze" had really occurred about the time of the death of Luther! The light of the conflagration had been speeding toward us across space at 186,000 miles a second, yet it has taken nearly three centuries to reach us. To be visible at all to us at that distance the fiery outbreak must have been stupendous. If a mass of petroleum ten times the size of the earth were suddenly fired it would not be seen at such a distance. The new star had increased its light many hundredfold in a few days.

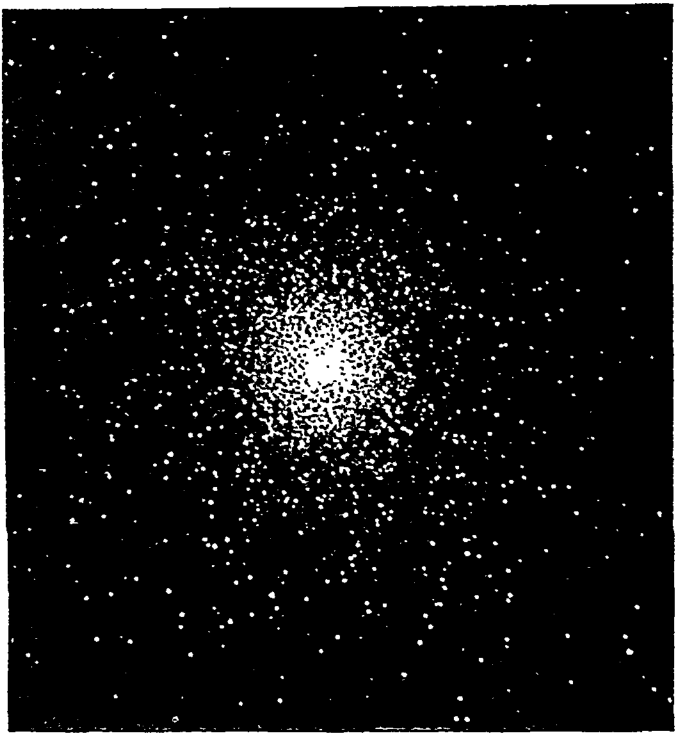


Photo: Astrophysical Observatory, Victoria, British Columbia.

FIG. 25.—STAR CLUSTER IN HERCULES.

A wonderful cluster of stars. It has been estimated that the distance of this cluster is such that it would take light more than 100,000 years to reach us.

There is a considerable fascination about the speculation that in such cases we see the resurrection of a dead world, a means of renewing the population of the universe. What happens is that in some region of the sky where no star, or only a very faint star, had been registered on our charts, we almost suddenly perceive a bright star. In a few days it may rise to the highest brilliancy. By the spectroscope we learn that this distant blaze means a prodigious outpour of white-hot hydrogen at hundreds of miles a second. But the star sinks again after a few months, and we then find a nebula round it on every side. It is natural to suppose that a dead or dying sun has somehow been reconverted in whole or in part into a nebula. A few astronomers think that it may have partially collided with another star, or approached too closely to another, with the result we described on an earlier page. The general opinion now is that a faint or dead star had rushed into one of those regions of space in which there are immense stretches of nebulous matter, and been (at least in part) vaporised by the friction. But the difficulties are considerable, and some astronomers prefer to think that the blazing star may merely have lit up a dark nebulæ which already existed. It is one of those problems on which speculation is most tempting but positive knowledge is still very incomplete. We may be content, even proud, that already we can take a conflagration that has occurred more than a thousand billion miles away and analyse it positively into an outflame of glowing hydrogen gas at so many miles a second.

THE SHAPE OF OUR UNIVERSE

§ 4

Our Universe a Spiral Nebulæ

What is the shape of our universe, and what are its dimensions? This is a tremendous question to ask. It is like asking an intelligent insect, living on a single leaf in the midst of a great Brazilian forest, to say what is the shape and size of

[illegible]

[illegible] GIANT SPIRAL NEBULA, March [illegible]

[illegible] the two spirals are emerging from it in opposite directions. [illegible] In either case we should get two streams in opposite directions [illegible]

6

the forest. Yet man's ingenuity has proved equal to giving an answer even to this question, and by a method exactly similar to that which would be adopted by the insect. Suppose, for instance, that the forest was shaped as an elongated oval, and the insect lived on a tree near the centre of the oval. If the trees were approximately equally spaced from one another they would appear much denser along the length of the oval than across its width. This is the simple consideration that has guided astronomers in determining the shape of our stellar universe. There is one direction in the heavens along which the stars appear denser than in the directions at right angles to it. That direction is the direction in which we look towards the Milky Way. If we count the number of stars visible all over the heavens, we find they become more and more numerous as we approach the Milky Way. As we go farther and farther from the Milky Way the stars thin out until they reach a maximum sparseness in directions at right angles to the plane of the Milky Way. We may consider the Milky Way to form, as it were, the equator of our system, and the line at right angles to point to the north and south poles.

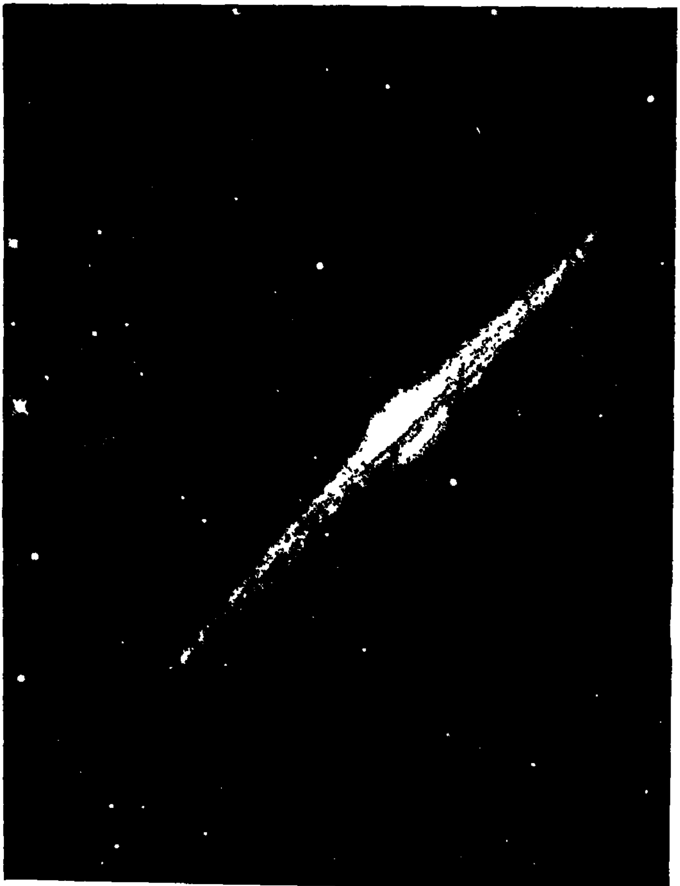


Photo: Mount Wilson Observatory.

FIG. 27.—A SPIRAL NEBULA SEEN EDGE-ON.

Notice the lens-shaped formation of the nucleus and the arm stretching as a band across it. See reference in the text to the resemblance between this and our stellar universe.

Our system, in fact, is shaped something like a lens, and our sun is situated near the centre of this lens. In the remoter part of this lens, near its edge, or possibly outside it altogether, lies the great series of star clouds which make up the Milky Way. All the stars are in motion within this system, but the very remarkable discovery has been made that these motions are not entirely random. The great majority of the stars whose motions can be measured fall into two groups drifting past one another in opposite directions. The velocity of one stream relative to the other is about twenty-five miles per second. The stars forming these two groups are thoroughly well mixed; it is not a case of an inner stream going one way and an outer stream the other. But there are not quite as many stars going one way as the other. For every two stars in one stream there are three in the other. Now, as we have said, some eminent astronomers hold that the spiral nebulæ are universes like our own, and if

THE SOLAR SYSTEM				
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
MERCURY	36.0	0.24	3010	0
VENUS	67.2	0.62	7700	0
EARTH	92.9	1.00	7918	1
MARS	141.5	1.88	4230	2
JUPITER	483.3	11.86	86500	9
SATURN	886.0	29.46	73000	10
URANUS	1781.9	84.02	31900	4
NEPTUNE	2791.6	164.79	34800	1
SUN	——	——	866400	——
MOON	——	——	2163	——

Fig. 28.

we look at the two photographs (figs. 26 and 27) we see that these spirals present features which, in the light of what we have just said about our system, are very remarkable. The nebula in Coma Berenices is a spiral edge-on to us, and we see that it has precisely the lens-shaped middle and the general flattened shape that we have found in our own system. The nebula in Canes Venatici is a spiral *facing* towards us, and its shape irresistibly suggests motions along the spiral arms. This motion, whether it is towards or away from the central, lens-shaped portion, would cause a double streaming motion in that central portion of the kind we have found in our own system. Again, and altogether apart from these considerations, there are good reasons for supposing our Milky Way to possess a double-armed spiral structure. And the great patches of dark absorbing matter which are known to exist in the Milky Way (see Fig. 24, p. 71) would give very much the mottled appearance we notice in the arms (which we see edge-on) of the nebula in Coma Berenices. The hypothesis, therefore, that our universe is a spiral nebula has much to be said for it. If it be accepted it greatly increases our estimate of the size of the material universe. For our central, lens-shaped system is calculated to extend towards the Milky Way for more than twenty thousand times a million million miles, and about a third of this distance towards what we have called the poles. If, as we suppose, each spiral nebula is an independent stellar universe comparable in size with our own, then, since there are hundreds of thousands of spiral nebulæ, we see that the size of the whole material universe is indeed beyond our comprehension.

In this simple outline we have not touched on some of the more debatable questions that engage the attention of modern astronomers. Many of these questions have not yet passed the controversial stage; out of these will emerge the astronomy of the future. But we have seen enough to convince us that, whatever

STAR DISTANCES	
STAR	*DISTANCE IN LIGHT-YEARS*
POLARIS	76
CAPELLA	49·4
RIGEL	466
SIRIUS	8·7
PROCYON	10·5
REGULUS	98·8
ARCTURUS	43·4
α CENTAURI	4·29
VEGA	34·7
SMALLER MAGELLANIC CLOUD (ESTIMATED)	32,600
GREAT CLUSTER IN HERCULES (ESTIMATED)	108,600

Fig. 29.

The above distances are merely approximate and are subject to further revision. A "light year" is the distance that light, travelling at the rate of 186,000 miles per second, would cover in one year.

advances the future holds in store, the science of the heavens constitutes one of the most important stones in the wonderful fabric of human knowledge.

ASTRONOMICAL INSTRUMENTS

§ 1

The Telescope.

The instruments used in modern astronomy are amongst the finest triumphs of mechanical skill in the world. In a great modern observatory the different instruments are to be counted by the score, but there are two which stand out pre-eminent as the fundamental instruments of modern astronomy. These instruments are the telescope and the spectroscope, and without them astronomy, as we know it, could not exist.

There is still some dispute as to where and when the first telescope was constructed; as an astronomical instrument, however, it dates from the time of the great Italian scientist, Galileo, who, with a very small and imperfect telescope of his own invention, first observed the spots on the sun, the mountains of the moon, and the chief four satellites of Jupiter. A good pair of modern binoculars is superior to this early instrument of Galileo's, and the history of telescope construction, from that primitive instrument to the modern giant recently erected on Mount Wilson, California, is an exciting chapter in human progress. But the early instruments have only an historic interest: the era of modern telescopes begins in the nineteenth century.

During the last century telescope construction underwent an unprecedented development. An immense amount of interest was taken in the construction of large telescopes, and the different countries of the world entered on an exciting race to produce the most powerful possible instruments. Besides this rivalry of different countries there was a rivalry of methods. The telescope developed along two different lines, and each of these two types has its partisans at the present day. These types are known as *refractors* and *reflectors*, and it is necessary to mention, briefly, the principles employed in each. The *refractor* is the ordinary, familiar type of telescope. It consists, essentially, of a large lens at one end of a tube, and a small lens, called the eye-piece, at the other. The function of the large lens is to act as a sort of gigantic eye. It collects a large amount of light, an amount proportional to its size, and brings this light to a focus within the tube of the telescope. It thus produces a small but bright image, and the eye-piece magnifies this image. In the *reflector*, instead of a large lens at the top of the tube, a large mirror is placed at the bottom. This mirror is so shaped as to reflect the light that falls on it to a focus, whence the light is again led to an eye-piece. Thus the refractor and the reflector differ chiefly in their manner of gathering light. The powerfulness of the telescope depends on the size of the light-gatherer. A telescope with a lens four inches in diameter is four times as powerful as one with a lens two inches in diameter, for the amount of light gathered obviously depends on the *area* of the lens, and the area varies as the *square* of the diameter.

The largest telescopes at present in existence are *reflectors*. It is much easier to construct a very large mirror than to construct a very large lens; it is also cheaper. A mirror is more likely to get out of order than is a lens, however, and any irregularity in the shape of a mirror produces a greater distorting effect than in a lens. A refractor is also more convenient to handle than is a reflector. For these reasons great refractors are still made, but the largest of them, the great Yerkes' refractor, is much smaller than the greatest reflector, the one on Mount Wilson, California. The lens of the Yerkes' refractor measures three feet four inches in diameter, whereas the Mount Wilson reflector has a diameter of no less than eight feet four inches.

But there is a device whereby the power of these giant instruments, great as it is, can be still further heightened. That device is the simple one of allowing the photographic plate to take the place of the human eye. Nowadays an astronomer seldom spends the night with his eye glued to the great telescope. He puts a photographic plate there. The photographic plate has this advantage over the eye,

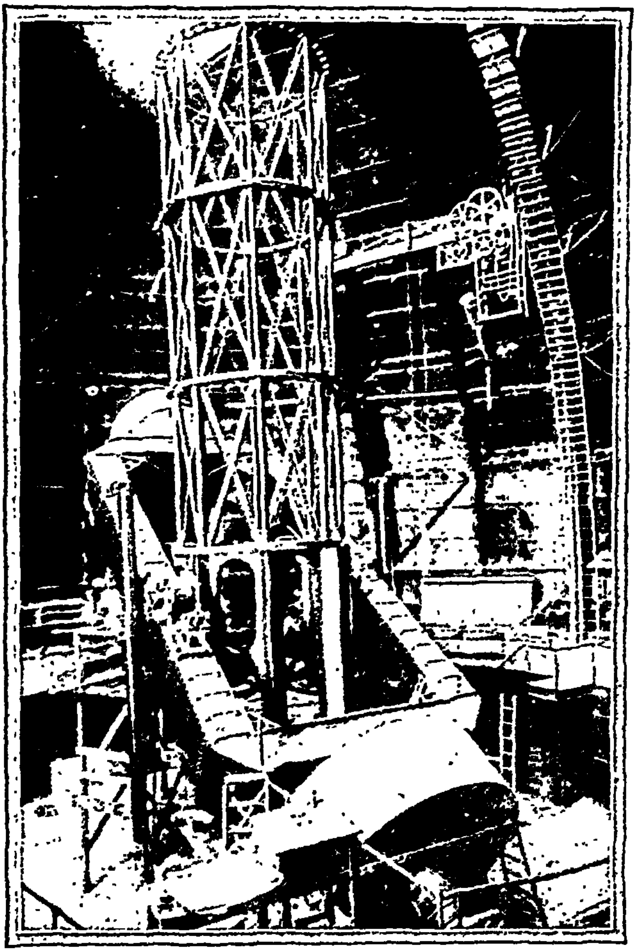


Photo: H. J. Shepstone.

100-INCH TELESCOPE, MOUNT WILSON.

A reflecting telescope: the largest in the world. The mirror is situated at the base of the telescope.

that it builds up impressions. However long we stare at an object too faint to be seen, we shall never see it. With the photographic plate, however, faint impressions go on accumulating. As hour after hour passes, the star which was too faint to make a perceptible impression on the plate goes on affecting it until finally it makes an impression which can be made visible. In this way the photographic plate reveals to us phenomena in the heavens which cannot be seen even through the most powerful telescopes.

Telescopes of the kind we have been discussing, telescopes for exploring the heavens, are mounted *equatorially*; that is to say, they are mounted on an inclined pillar parallel to the axis of the earth so that, by rotating round this pillar, the telescope is enabled to follow the apparent motion of a star due to the rotation of the earth. This motion is effected by clock-work, so that, once adjusted on a star, and the clock-work started, the telescope remains adjusted on that star for any length of time that is desired. But a great official observa-

tory, such as Greenwich Observatory or the Observatory at Paris, also has *transit* instruments, or telescopes smaller than the equatorials and without the same facility of movement, but which, by a number of exquisite refinements, are more adapted to accurate measurements. It with much greater accuracy than is possible to the more general and flexible mounting of equatorials. The recording of transits is comparatively dry work; the spectacular element is entirely absent; stars are treated merely as mathematical points. But these observations

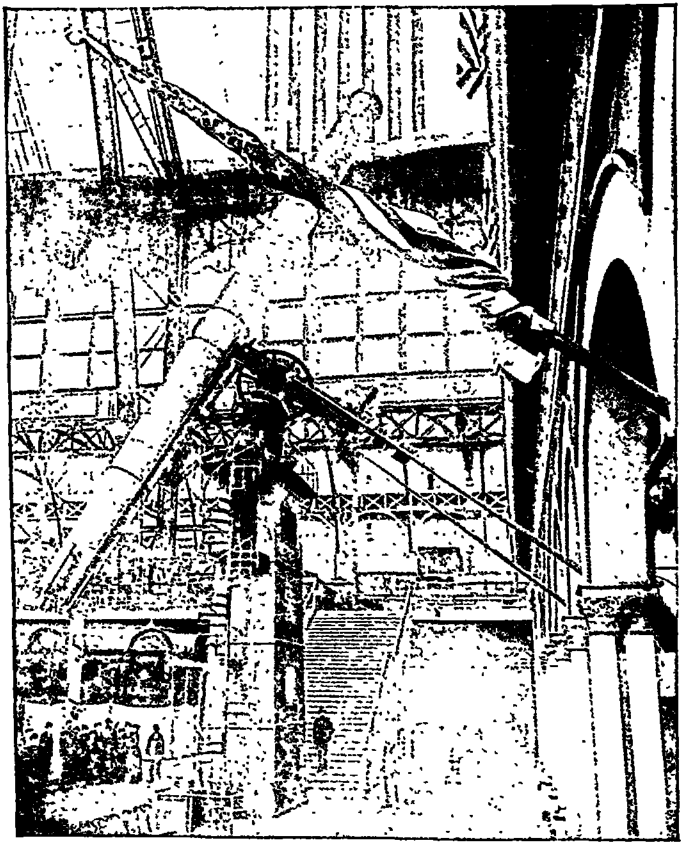


Photo: H. J. Shepstone.

40-INCH YERKES TELESCOPE.

Showing the dimensions of the greatest refractor in the world. The floor of the observatory rises or falls several feet according as the telescope is inclined, thus enabling the observer to remain at the eye-piece.

is these instruments which are chiefly used in the compilation of the *Nautical Almanac*. They do not follow the apparent motions of the stars. Stars are allowed to drift across the field of vision, and as each star crosses a small group of parallel wires in the eye-piece its precise time of passage is recorded. Owing to their relative fixity of position these instruments can be constructed to record the *positions* of stars furnish the very basis of modern mathematical astronomy, and without them such publications as the *Nautical Almanac* and the *Connaissance du Temps* would be robbed of the greater part of their importance.

§ 2

We have already learnt something of the principles of the spectroscope, the instrument

which by making it possible to learn the actual constitution of the stars, has added a vast new domain to astronomy. In the simplest form of this instrument the analysing portion consists of a single prism. Unless the prism is very large, however, only a small degree of dispersion is obtained. It is obviously desirable, for accurate analytical work, that the dispersion—that is, so that unless our primary source of light is very strong, the final spectrum will be very feeble and hard to decipher.

The Spectroscope.

Another way of obtaining considerable dispersion is by using a *diffraction grating* instead of a prism. This consists essentially of a piece of glass on which lines are ruled by a diamond point. When the lines are sufficiently close together they split up light falling on them into

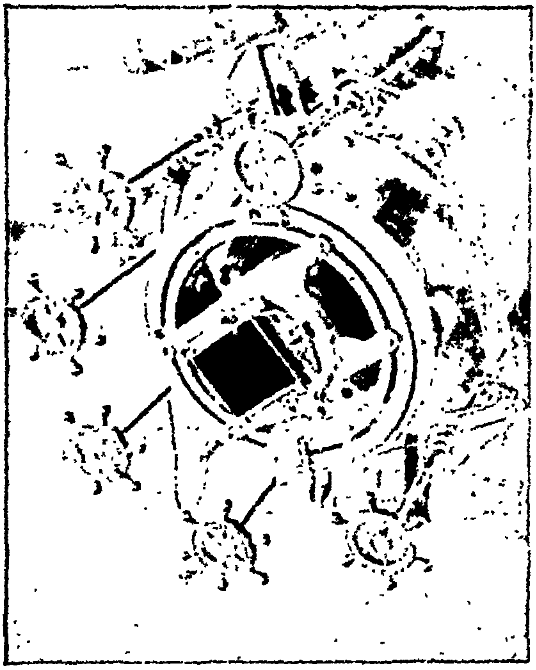


Photo: H. J. Shepstone

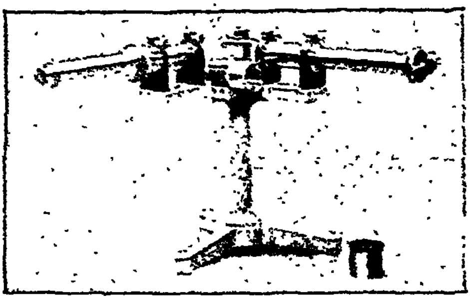
THE DOUBLE-SLIDE PLATE HOLDER ON YERKES 40-INCH REFRACTING TELESCOPE.

The smaller telescope at the top of the picture acts as a "finder"; the field of view of the large telescope is so restricted that it is difficult to recognize, as it were, the part of the heavens being surveyed. The smaller telescope takes in a larger area and enables the precise object to be examined to be easily selected.

the separation of the different parts of the spectrum—should be as great as possible. The dispersion can be increased by using a large number of prisms, the light emerging from the first prism, entering the second, and so on. In this way each prism produces its own dispersive effect and when a number of prisms is employed, the final dispersion is considerable. A considerable amount of light is absorbed in this way, however, its constituents and produce a spectrum. The modern diffraction grating is a truly wonderful piece of work. It contains several thousands of lines to the inch, and these lines have to be spaced with the greatest accuracy. But in this instrument, again, there is a considerable loss of light.

We have said that every substance has its own distinctive spectrum, and it might be thought that, when a list of the spectra

of different substances has been prepared, spectrum analysis would become perfectly straightforward. In practice, however, things are not quite so simple. The spectrum emitted by a substance is influenced by a variety of conditions. The pressure, the temperature, the state of motion of the object we are observing, all make a difference, and one of the most laborious tasks of the modern spectroscopist is to disentangle these effects from one another. Simple as it is in its broad outlines, spectroscopy is, in reality, one of the most intricate branches of modern science.



MODERN DIRECT-READING SPECTROSCOPE.

(By A. Hilger, Ltd.)

The light is brought through one telescope, is split up by the prism, and the resulting spectrum is observed through the other telescope.

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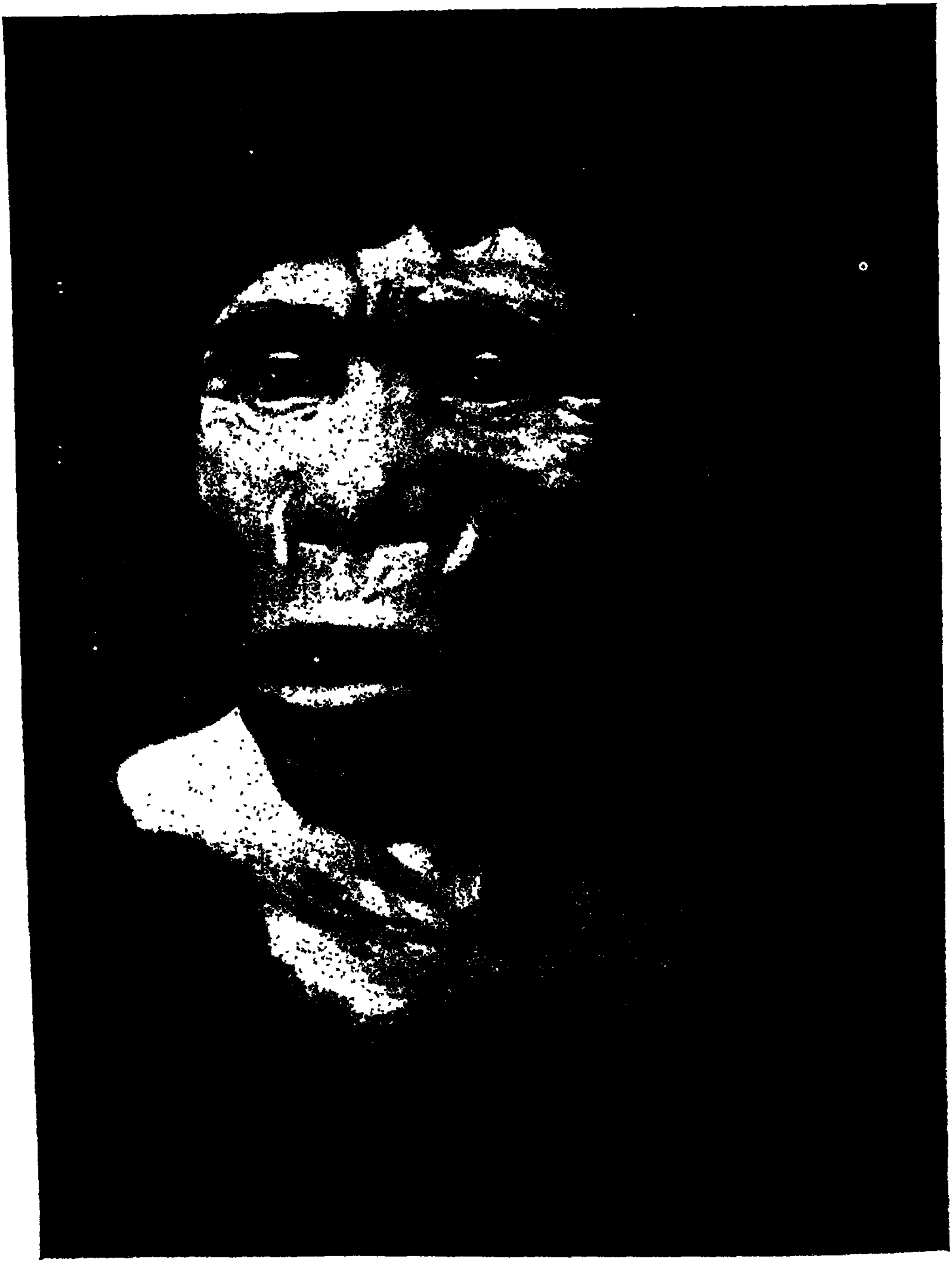


A RECONSTRUCTION OF THE JAVA MAN

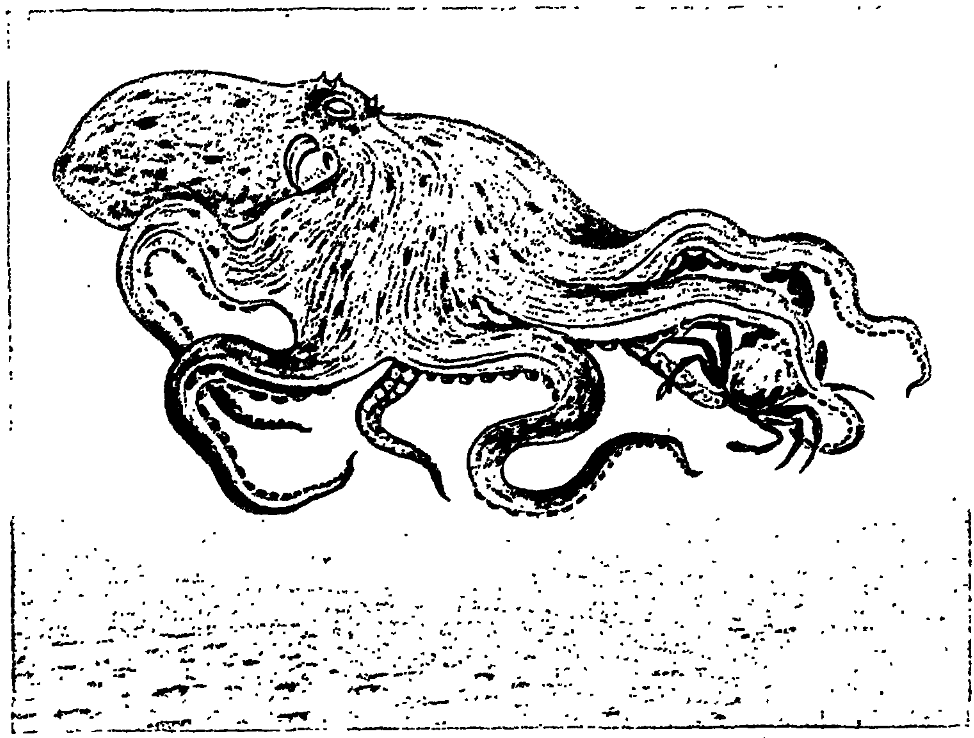
(*Pithecanthropus erectus*).

See *The Ascent of Man*, p. 110.

III

ADAPTATIONS TO ENVIRONMENT

WE saw in a previous chapter how the process of evolution led to a mastery of all the haunts of life. But it is necessary to return to these haunts or homes of animals in some detail, so as to understand the peculiar circumstances of each, and to see how in the course of ages of struggle all sorts of self-preserving and race-continuing adaptations or fitnesses have been wrought out and firmly established. Living creatures have spread over all the earth and in the waters under the earth; some of them have conquered the underground world and others the air. It is possible, however, as has been indicated, to distinguish six great haunts of life, each tenanted by a distinctive fauna, namely, the shore of the sea, the open sea, the depths of the sea, the fresh-waters, the dry land, and the air. In the deep sea there are no plants at all; in the air the only plants are floating bacteria, though there is a sense in which a tree is very aerial, and the orchid perched on its branches still more so; in the other four haunts there is a flora as well as a fauna—the two working into one another's hands in interesting and often subtle inter-relations—the subject of a separate study.

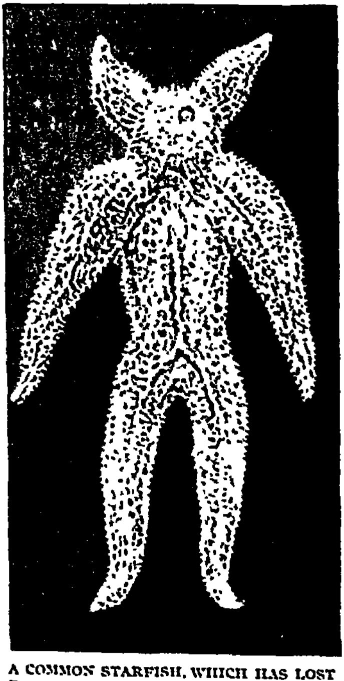


AN EIGHT-ARMED CUTTLEFISH OR OCTOPUS ATTACKING A SMALL CRAB.

These molluscs are particularly fond of crustaceans, which they crunch with their parrot's-beak-like jaws. Their salivary juice has a paralysing effect on their prey. To one side, below the eye, may be seen the funnel through which water is very forcibly ejected in the process of locomotion.

I. THE SHORE OF THE SEA

By the shore of the sea the zoologist means much more than the narrow zone between tide-marks; he means the whole of the relatively shallow, well-illumined, seaweed-growing shelf around the continents and continental islands. Technically, this is called the littoral area, and it is divisible into zones, each with its characteristic population. It may be noted that the green seaweeds are highest up on the shore; the brown ones come next; the beautiful red ones are lowest. All of them have got green chlorophyll, which enables them to utilise the sun's rays in photosynthesis (i.e. building up carbon compounds from air, water, and salts), but in the brown and red seaweeds the green pigment is masked by others. It is maintained by some botanists that these other pigments enable their possessors to make more of the scantier light in the deeper waters. However this may be, we must always think of the shore-haunt as the seaweed-growing area. Directly and indirectly the life of the shore animals is closely wrapped up with the seaweeds, which afford food and foothold, and temper the force of the waves. The minute fragments broken off from seaweeds and from the sea-grass (a flowering plant called Zostera) form a sort of nutritive sea-dust which is swept slowly down the slope from the shore, to form a very useful deposit in the quietness of deepish water. It is often found in the stomachs of marine animals living a long way offshore.



A COMMON STARFISH, WHICH HAS LOST THREE ARMS AND IS REGROWING THEM.
The lowest arm is being regrown double.
(After Professor W. C. McIntosh.)

The Seaweed Area.

Conditions of Shore Life.

The littoral area as defined is not a large haunt of life; it occupies only about 9 million square miles, a small fraction of the 197,000,000 of the whole earth's surface. But it is a very long haunt, some 150,000 miles, winding in and out by bay and fiord, estuary and creek. Where deep water comes close to cliffs there may be no shore at all; in other places the relatively shallow water, with seaweeds growing over the bottom, may extend outwards for miles. The nature of the shore varies greatly according to the nature of the rocks, according to what the streams bring down from inland, and according to the jetsam that is brought in by the tides. The shore is a changeful place; there is, in the upper reaches, a striking difference between "tide in" and "tide out"; there are vicissitudes due to storms, to freshwater floods, to wind-blown sand, and to slow changes of level, up and down. The shore is a very crowded haunt, for it is comparatively narrow, and every niche among the rocks may be precious.

Keen Struggle for Existence.

It follows that the shore must be the scene of a keen struggle for existence—which includes all the answers-back that living creatures make to environing difficulties and limitations. There is struggle for food, accentuated by the fact that small items tend to be swept away by the outgoing tide or to sink down the slope to deep water. Apart from direct competition, e.g. between hungry hermit-crabs, it often involves hard work to get a meal. This is true even of apparently sluggish creatures. Thus the Crumb-of-Bread Sponge, or any other seashore sponge, has to lash large quantities of water through the intricate canal system of its body before it can get a sufficient supply of the microscopic organisms and organic particles on which it feeds. An index of the intensity of the struggle for food is afforded by the nutritive chains which bind animals together. The shore is almost noisy with the conjugation of the

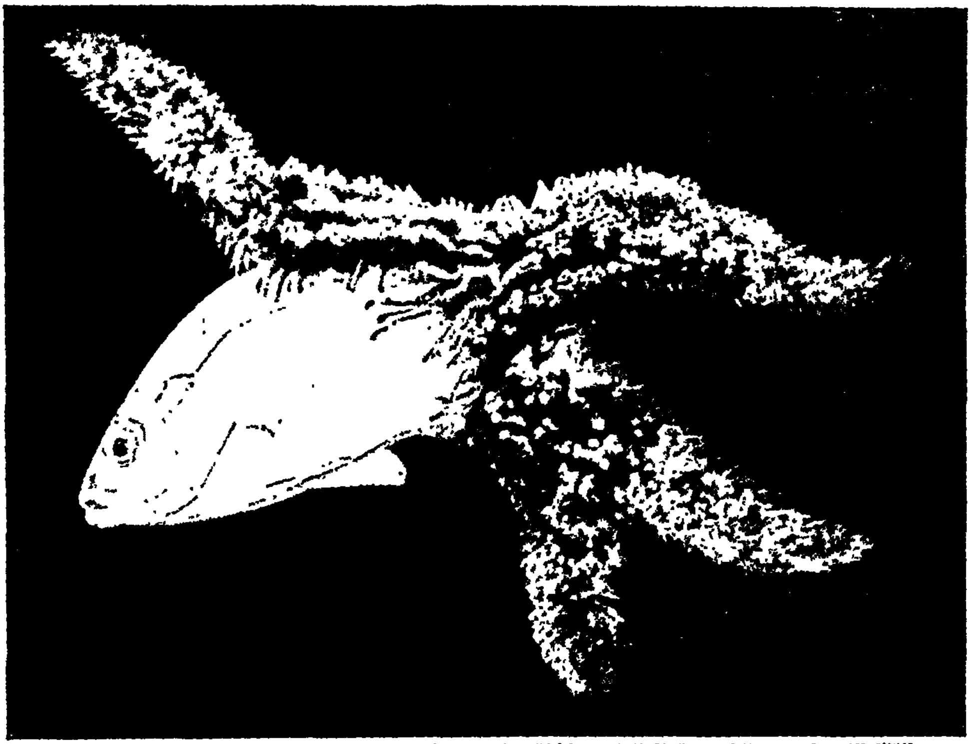
verb to eat in its many tenses. One pound of rock-cod requires for its formation ten pounds of whelk; one pound of whelk requires ten pounds of sea-worms; and one pound of worms requires ten pounds of sea-dust. Such is the circulation of matter, ever passing from one embodiment or incarnation to another.

Besides struggle for food there is struggle for foothold and for fresh air, struggle against the scouring tide and against the pounding breakers. The risk of dislodgment is often great and the fracture of limbs is a common accident. Of kinds of armour—the sea-urchin's hedgehog-like test, the crab's shard, the limpet's shell—there is great variety, surpassed only by that of weapons—the sea-anemone's stinging-cells, the sea-urchin's snapping-blades, the *hermit-crab's forceps, the grappling tentacles* and parrot's-beak jaws of the octopus.

We get another glimpse of the intensity of the seashore struggle for existence in the frequency of "shifts for a living," adaptations of structure or of behaviour which meet frequently recurrent vicissitudes.

Shifts for a Living.

The starfish is often in the dilemma of losing a limb or its life; by a reflex action it jettisons the captured arm and escapes. And what is lost is gradually regrown. The crab gets its leg broken past all mending; it casts off the leg across a weak breakage plane near the base, and within a preformed bandage which prevents bleeding a new leg is formed in miniature. Such is the adaptive device—more reflex than reflective—which is called self-mutilation or autotomy.



A PHOTOGRAPH SHOWING A STARFISH (*ASTERIAS FORRERI*) WHICH HAS CAPTURED A LARGE FISH.

The suctorial tube feet are seen gripping the fish firmly. (After an observation on the Californian coast.)

In another part of this book there is a discussion of camouflaging and protective resemblance; how abundantly these are illustrated on the shore! But there are other "shifts for a living." Some of the sand-hoppers and their

relatives illustrate the puzzling phenomenon of "feigning death," becoming suddenly so motionless that they escape the eyes of their enemies. Cuttlefishes, by discharging sepia from their ink-bags, are able to throw dust in the eyes of their enemies. Some undisguised shore-animals, e.g. crabs, are adepts in a hide-and-seek game; some fishes, like the butterfish or gunnel, escape between stones where there seemed no opening and are almost uncatchable

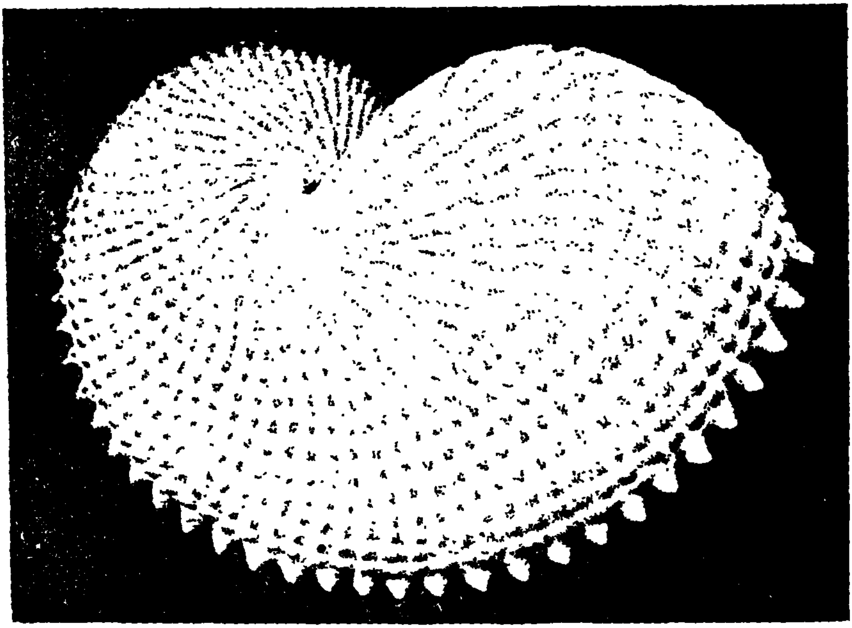


Photo: J. J. Ward, F.E.S.

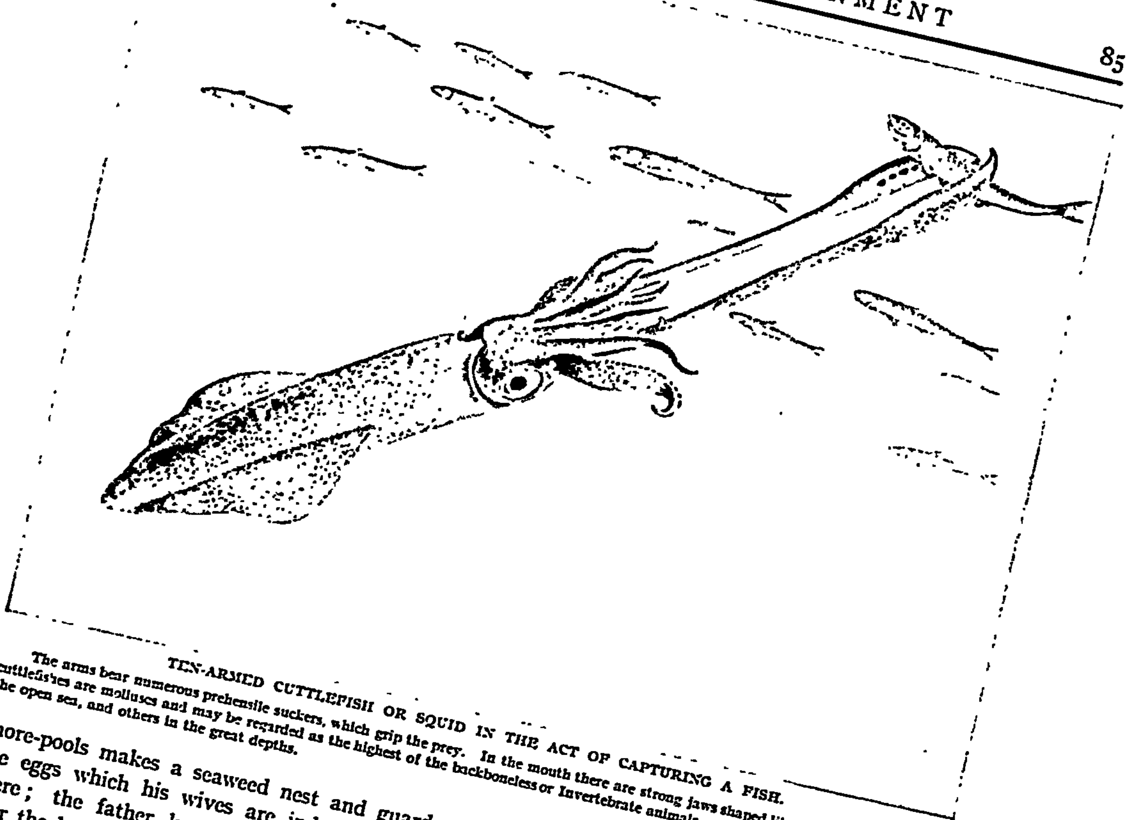
THE PAPER NAUTILUS (ARGONAUTA), AN ANIMAL OF THE OPEN SEA.

The delicate shell is made by the female only, and is used as a shelter for the eggs and young ones. It is secreted by two of the arms, not by the mantle as other mollusc shells are. It is a single-chambered shell, very different from that of the Pearly Nautilus.

in their slipperiness. Subtlest of all, perhaps, is the habit some hermit-crabs have of entering into mutually beneficial partnership (commensalism) with sea-anemones, which mask their bearers and also serve as mounted batteries, getting transport as their reward and likewise crumbs from the frequently spread table. But enough has been said to show that the shore-haunt exhibits an extraordinary variety of shifts for a living.

According to Darwin, the struggle for existence, as a big fact in the economy of Animate Nature, includes not only competition but all the endeavours which secure the welfare of the offspring, and give them a good send-off in life. So it is without a jolt that we pass from struggle for food and foothold to parental care. The marine leech called Pontobdella, an interesting greenish warty creature fond of fixing itself to skate, places its egg-cocoons in the empty shell of a bivalve mollusc, and guards them for weeks, removing any mud that might injure their development. We have seen a British starfish with its fully-formed young ones creeping about on its body, though the usual mode of development for shore starfishes is that the young ones pass through a free-swimming larval period in the open water. The father sea-spider carries about the eggs attached to two of his limbs; the father sea-horse puts his mate's eggs into his breast pocket and carries them there in safety until they are hatched; the father stickleback of the

Parental Care on the Shore.



TEN-ARMED CUTTLEFISH OR SQUID IN THE ACT OF CAPTURING A FISH.
The arms bear numerous prehensile suckers, which grip the prey. In the mouth there are strong jaws shaped like a parrot's beak. The cuttlefishes are molluscs and may be regarded as the highest of the backboneless or Invertebrate animals. Many occur near shore, others in the open sea, and others in the great depths.

shore-pools makes a seaweed nest and guards the eggs which his wives are induced to lay there; the father lumpsucker mounts guard over the bunch of pinkish eggs which his mate has laid in a nook of a rocky shore-pool, and drives off intruders with zest. He also aerates the developing eggs by frequent paddling with his pectoral fins and tail, as the Scots name Cock-paidle probably suggests. It is interesting that the salient examples of parental care in the shore-haunt are mostly on the male parent's side. But there is maternal virtue as well.

The fauna of the shore is remarkably *representative*—from unicellular Protozoa to birds like the oyster-catcher and mammals like the seals. Almost all the great groups of animals have apparently served an apprenticeship in the shore-haunt, and since lessons learned for millions of years sink in and become organically enregistered, it is justifiable to look to the shore as a great school in which were gained racial qualities of endurance, patience, and alertness.

II. THE OPEN SEA

In great contrast to the narrow, crowded, difficult conditions of the shore-haunt (littoral area) are the spacious, bountiful, and relatively easygoing conditions of the open sea (pelagic area), which means the well-lighted surface waters quite away from land. Many small organisms have their maximum abundance at about fifty fathoms, so that the word "surface" is to be taken generously. The light becomes very dim at 250 fathoms, and the open sea, as a zoological haunt, stops with the light. It is hardly necessary to say that the pelagic plants are more abundant near the surface, and that below a certain depth the population

consists almost exclusively of animals. Not a few of the animals sink and rise in the water periodically; there are some that come near the surface by day, and others that come near the surface by night. Of great interest is the habit of the extremely delicate Ctenophores or "sea-gooseberries," which the splash of a wave would tear into shreds. Whenever there is any hint of a storm they sink beyond its reach, and "the ocean's surface must have remained flat as a mirror for many hours before they can be lured upwards from the calm of their deep retreat."

MINUTE TRANSPARENT EARLY STAGE OF A SEA-CUCUMBER.

It swims in the open sea by means of girdles of microscopic cilia shown in the figure. After a period of free-swimming and a remarkable metamorphosis, the animal settles down on the floor of the sea in relatively shallow water.

To understand the vital economy of the open sea, we must recognise the incalculable abundance of minute unicellular plants, for they form the fundamental food-supply. Along with these must also be included numerous microscopic animals which have got possession of chlorophyll, or have entered into internal partnership with unicellular Algæ (symbiosis). These green or greenish plants and animals are the *producers*, using the energy of the sunlight to help them in building up carbon compounds out of air, water, and salts. The animals which feed on the producers, or on other animals, are the *consumers*. Between the two come those open-sea bacteria that convert nitrogenous material, e.g. from dead plants or animals that other bacteria have rotted, into forms, e.g. nitrates, which plants can re-utilise. The importance of these *middlemen* is great in keeping "the circulation of matter" agoing.

The Floating Sea-meadows.

The "floating sea-meadows," as Sir John Murray called them, are always receiving contributions from inshore waters, where the conditions are favourable for the prolific multiplication of unicellular Algæ, and there is also a certain amount of non-living sea-dust always

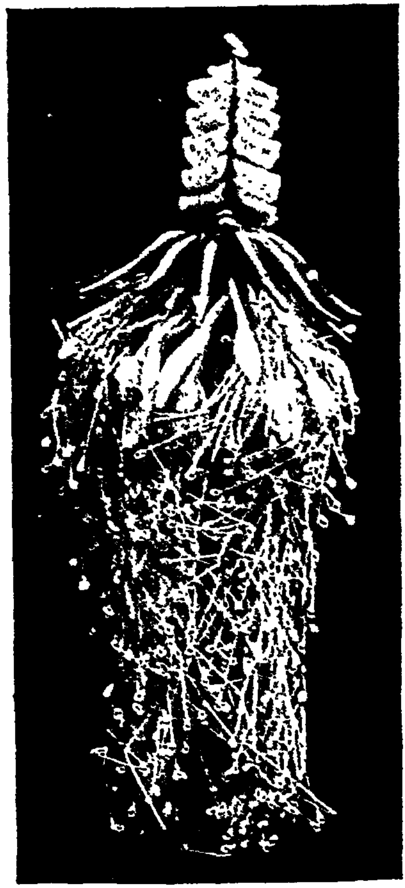


Photo: British Museum (Natural History).

AN INTRICATE COLONY OF OPEN-SEA ANIMALS (*PHYSOPHORA HYDROSTATICA*) RELATED TO THE PORTUGUESE MAN-OF-WAR.

There is great division of labour in the colony. At the top are floating and swimming "persons": the long ones below are offensive "persons" bearing batteries of stinging cells; in the middle zone there are nutritive, reproductive, and other "persons." The colour of the colony is a fine translucent blue. Swimmers and bathers are often badly stung by this strange animal and its relatives.

been swept out from the seaweed and sargasso area.

Swimmers and Drifters.

The animals of the open sea are conveniently divided into the active swimmers (Nekton) and the more passive drifters (Plankton). The swimmers include whales great and small, such birds as the storm-petrel, the fish-eating turtles and sea-snakes, such fishes as mackerel and herring, the winged snails or sea-butterflies on which whalebone whales largely feed, some of the active cuttles or squids, various open-sea prawns and their relatives, some worms like the transparent arrow-worm, and such active Protozoa as Noctiluca, whose luminescence makes the waves sparkle in the short summer darkness. Very striking as an instance of the insurgence of life are the sea-skimmers (Halobatidæ), wingless insects related to the water-measurers in the ditch. They are found hundreds of miles from land, skimming on the surface of the open sea, and diving in stormy weather. They feed on floating dead animals.

The drifters or easygoing swimmers—for there is no hard and fast line—are represented, for instance, by the flinty-shelled Radiolarians and certain of the chalk-forming animals (Globigerinid Foraminifera); by jellyfishes, swimming-bells, and Portuguese men-of-war; by the comb-bearers or Ctenophores; by legions of minute Crustaceans; by strange animals called Salps, related to the sedentary sea-squirts; and by some sluggish fishes like globe-fishes, which often float idly on the surface.

GREENLAND WHALE.

Showing the double blowhole or nostrils on the top of the head and the whalebone plates hanging down from the roof of the mouth.

Open-sea animals tend to be delicately built, with a specific gravity near that of the sea-water, with adaptations, such as projecting filaments, which help flotation, and with capacities of rising and sinking according to the surrounding conditions. Many of them are luminescent, and many of them are very inconspicuous in the water owing to their transparency or their bluish colour. In both cases the significance is obscure.

Hunger is often very much in evidence in

A SCENE IN THE GREAT DEPTHS.

Showing a deep-sea fish of large gape, two feather-stars on the end of long stalks, a "sea-spider" (or Pycnogon) walking on lanky legs on the treacherous ooze, likewise a brittle-star, and some deep-sea corals.

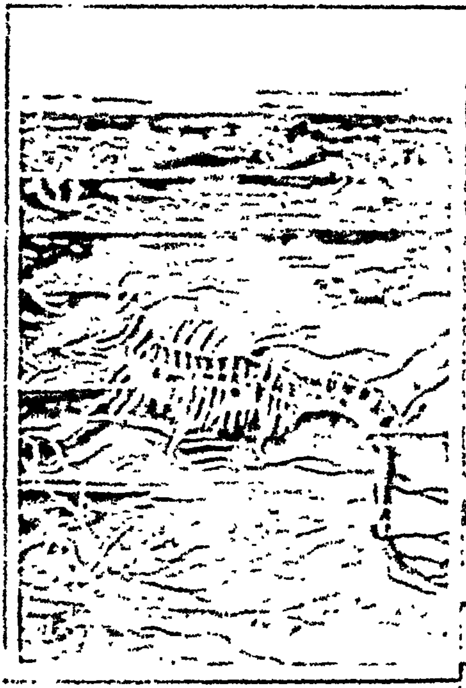
the open sea, especially in areas where the Plankton is poor. For there is great diversity in this respect, most of the Mediterranean, for instance, having a scanty Plankton as compared with the North Sea. In the South Pacific, west of Patagonia, there is said to be an immense "sea-desert" where there is little Plankton, and therefore little in the way of fishes. The success of fisheries in the North, e.g. on the Atlantic cod-banks, is due to the richness of the floating sea-meadows and the abundance of the smaller constituents of the animal Plankton.

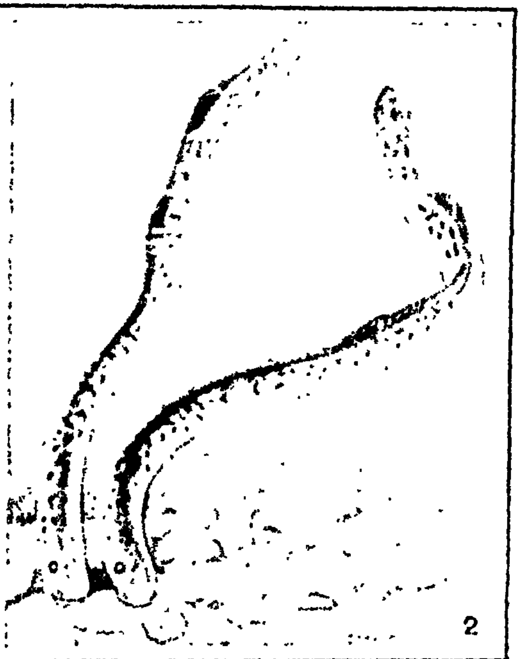
Hunger and Love.

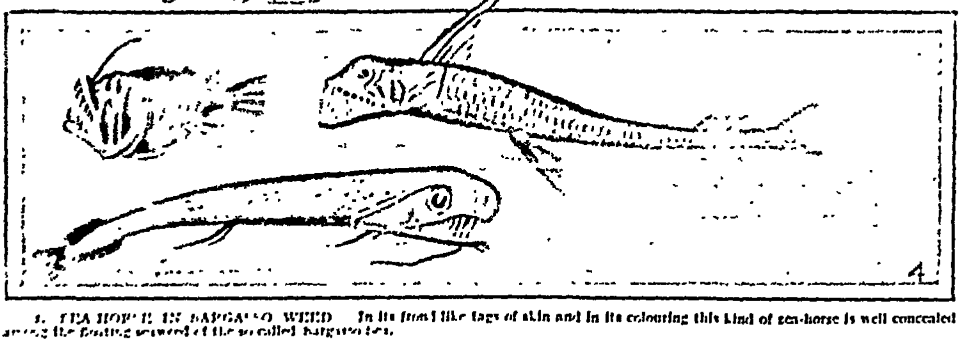
Hunger is plain enough when the Baleen Whale rushes through the water with open jaws, engulfing in the huge cavern of its mouth, where the pendent whalebone plates form a huge sieve, incalculable millions of small fry.

But there is love as well as hunger in the open sea. The maternal care exhibited by the whale reaches a very high level, and the delicate shell of the female Paper Nautilus or Argonaut, in which the eggs and the young ones are sheltered, may well be described as "the most beautiful cradle in the world."

Besides the permanent inhabitants of the open sea, there are the larval stages of many shore-animals which are there only for a short time. For there is an interesting give and take between the shore-haunt and the open sea. From the shore come nutritive contributions and minute organisms which multiply quickly in the open waters. But not less important is the fact that the open waters afford a safe cradle or nursery for many a delicate larva, e.g. of crab and starfish, acorn-shell and sea-urchin, which could not survive for a day in the rough-and-tumble conditions of the shore and the shallow water. After undergoing radical changes and gaining strength, the young creatures return to the shore in various ways.







1. *SEA-HORSE IN SARGASSO WEED.* In its frond-like tags of skin and in its colouring this kind of sea-horse is well concealed among the floating seaweed of the so-called Sargasso Sea.

2. THE LARGE MARINE LAMPREYS (*PETROMYZON MARINUS*), WHICH MAY BE AS LONG AS ONE'S ARM, SPAWN IN FRESH WATER. Stones and pebbles, gripped in the suctorial mouth, are removed from a selected spot and piled around the circumference, so that the eggs, which are laid within the circle, are not easily washed away.

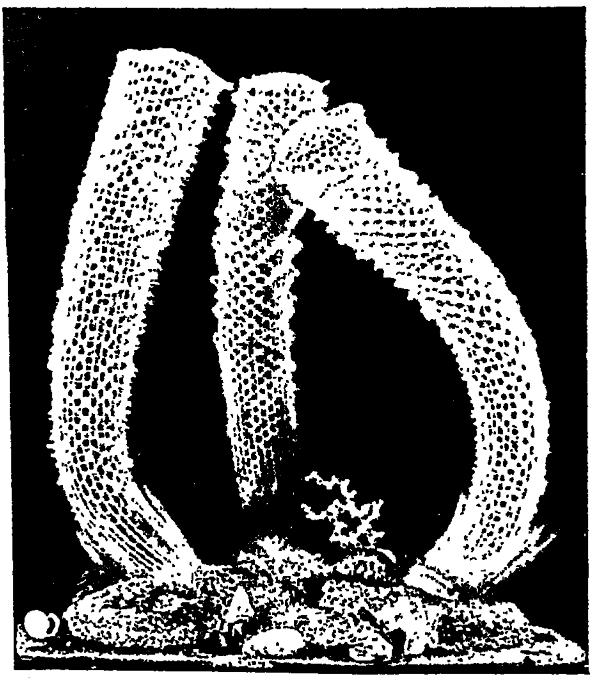
3. THE DEEP-SEA FISH *CHIASMODON NIGER* IS FAMOUS FOR ITS VORACITY. It sometimes manages to swallow a fish larger than itself, which causes an extraordinary protrusion of the stomach.

4. DEEP-SEA FISHES. Two of them—*Melanocetus murrayi* and *Melanocetus indicus*—are related to the Angler of British coasts, but adapted to life in the great abysses. They are very dark in colour, and delicately built; they possess well-developed luminous organs. The third form is called Chauliodus, a predatory animal with large gape and formidable teeth.

III. THE DEEP SEA

Very different from all the other haunts are the depths of the sea, including the floor of the abysses and the zones of water near the bottom. This haunt, forever unseen, occupies more than a third of the earth's surface, and it is thickly peopled. It came into emphatic notice in connection with the mending of telegraph cables, but the results of the *Challenger* expedition (1873–6) gave the first impressive picture of what was practically a new world.

Physical Conditions. The average depth of the ocean is about two and a half miles; therefore, since many parts are relatively shallow, there must be enormous depths. A few of these, technically called "deeps," are about six miles deep, in which Mount Everest would be engulfed. There is enormous pressure in such depths; even at 2,500 fathoms it is two and a half tons on the square inch. The temperature is on and off the freezing-point of fresh water (28°–34° Fahr.), due to the continual sinking down of cold water from the Poles, especially from the South. Apart from the fitful gleams of luminescent animals, there is utter darkness in the deep waters. The rays of sunlight are practically extinguished at 250 fathoms, though very sensitive bromo-gelatine plates exposed at 500 fathoms have shown faint indications even at that depth. It is a world of absolute calm and silence, and there is no scenery on the floor. A deep, cold, dark, silent, monotonous world!



FLINTY SKELETON OF VENUS FLOWER BASKET (EUPLECTELLA), A JAPANESE DEEP SEA SPONGE.

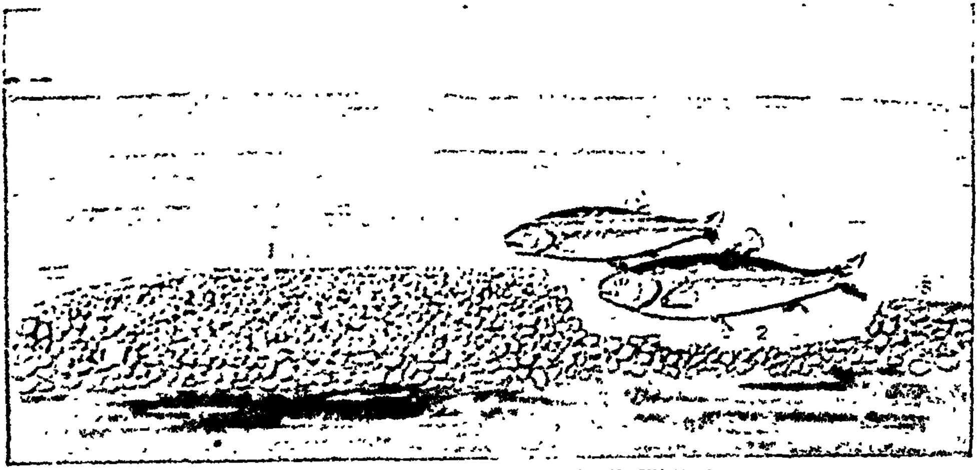
Biological Conditions. While some parts of the floor of the abysses are more thickly peopled than others, there is no depth limit to the distribution of life. Wherever the long arm of the dredge has reached, animals have been found, e.g. Protozoa, sponges, corals, worms, starfishes, sea-urchins, sea-lilies, crustaceans, lamp-shells, molluscs, ascidians, and fishes—a very representative fauna. In the absence of light there can be no chlorophyll-possessing plants, and as the animals cannot all be eating one another there must be an extraneous source of food-supply. This is found in the sinking down of minute organisms which are killed on the surface by changes of temperature and other causes. What is left of them, before or after being swallowed, and of sea-dust and mineral particles of various kinds forms the diversified "ooze" of the sea-floor, a soft muddy precipitate, which is said to have in places the consistence of butter in summer weather.

There seem to be no bacteria in the abysses, so there can be no rotting. Everything that sinks down, even the huge carcase of a whale, must be nibbled away by hungry animals and digested, or else, in the case of most bones, slowly dissolved away. Of the whale there are left only the ear-bones, of the shark his teeth.

In adaptation to the great pressure the bodies of deep-sea animals are usually very permeable,

so that the water gets through and through them, as in the case of Venus' Flower Basket, a flinty sponge which [illegible] world-show. But when the ground is muddy, [illegible] happen. In adaptation to the treacherous ooze, so apt to smother, many of the active deep-sea animals have very long, stilt-like legs, and many of the sedentary types are lifted into safety on the end of long stalks, which have their bases embedded in the mud. In adaptation to the darkness, in which there is only luminescence that eyes could use, there is a

Adaptations to Deep-sea Life.



EGG DEPOSITORY OF SEMOTILUS ATROMACULATUS

In the beginning of the egg depository, the male fish takes stones from the bottom of the stream, gripping them in his mouth, and heaps them up into the dam. In the egg depository he arranges the stones so that when the eggs are deposited in the interstices they are thoroughly protected and cannot be washed down stream.

1, dam of stones; 2, egg depository; 3, hillock of sand. The arrow shows the direction of the stream. Upper fish, male; lower, female.

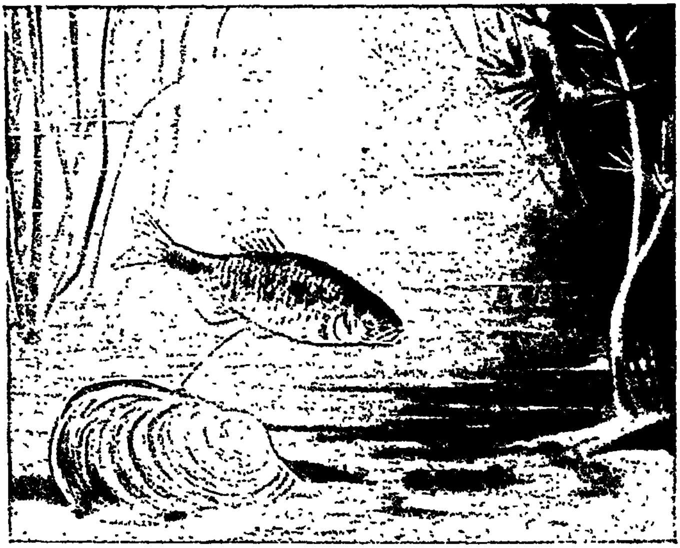
great development of tactility. The interesting problem of luminescence will be discussed elsewhere.

As to the origin of the deep-sea fauna, there seems no doubt that it has arisen by many contributions from the various shore-haunts. Following the down-drifting food, many shore-animals have in the course of many generations reached the world of eternal night and winter, and become adapted to its strange conditions. For the animals of the deep-sea are as fit, beautiful, and vigorous as those elsewhere. There are no slums in Nature.

IV. THE FRESHWATERS

Of the whole earth's surface the freshwaters form a very small fraction, about a hundredth, but they make up for their smallness by their variety. We think of deep lake and shallow pond, of the great river and the purling brook, of lagoon and swamp, and more besides. There is a striking resemblance in the animal population of widely separated freshwater basins, and this is partly because birds carry many small creatures on their muddy feet from one watershed to another; partly because some of the freshwater animals are descended from types which made their way from the sea and the seashore through estuaries and marshes, and only certain kinds of constitution could survive the migration; and partly because some lakes are landlocked dwindling relics of ancient seas, and similar forms again would survive the change.

A typical assemblage of freshwater animals would include many Protozoa, like Amœbæ and the Bell-Animalcules, a representative of one family of sponges (Spongillidæ), the common Hydra, many unsegmented worms (notably Planarians and Nematodes), many Annelids related to the earthworms, many crustaceans,



THE BITTERLING (*RHODEUS AMARUS*).
A Continental fish which lays its eggs by means of a long ovipositor inside the freshwater mussel. The eggs develop inside the mollusc's gill-plates.

insects, and mites, many bivalves and snails, various fishes, a newt or two, perhaps a little mud-turtle or in warm countries a huge Crocodilian, various interesting birds like the water-ouzel or dipper, and mammals like the water-vole and the water-shrew.

Freshwater animals have to face certain difficulties, the greatest of which are drought, frost, and being washed away in times of flood. There is no more interesting study in the world than an inquiry into the adaptations by which freshwater animals overcome the difficulties of the situation. We cannot give more than a few illustrations.

(1) Drought is circumvented by the capacity that many freshwater animals have of lying low and saying nothing. Thus the African mudfish may spend half the year encased in the mud, and many minute crustaceans can survive being dried up for years. (2) Escape from the danger of being frozen hard in the pool is largely due to the almost unique property of water that it expands as it approaches the freezing-point. Thus the colder water rises to the surface and forms or adds to the protecting blanket of ice. The warmer water remains unfrozen at the bottom, and the animals live on. (3) The risk of being washed away, e.g. to the sea, is lessened by all sorts of gripping, grappling, and anchoring structures, and by shortening the juvenile stages when the risks are greatest.

V. THE DRY LAND

Over and over again in the history of animal life there have been attempts to get out of the water on to terra firma, and many of these have been successful, notably those made (1) by worms, (2) by air-breathing Arthropods, and (3) by amphibians.

In thinking of the conquest of the dry land by animals, we must recognise the indispensable rôle of plants in preparing the way. The dry ground would have proved too inhospitable had not terrestrial plants begun to establish themselves, affording food, shelter, and humidity. There had to be plants before there could be earthworms, which feed on decaying leaves and the like, but how soon was the debt repaid when the earthworms began their worldwide task of forming vegetable mould, opening up the earth with their burrows, circulating the soil by means of their castings, and bruising the particles in their gizzard—certainly the most important mill in the world.

Another important idea is that littoral haunts, both on the seashore and in the freshwaters,

afforded the necessary apprenticeship and transitional experience for the more strenuous life on dry land. Much that was perfected on land had its beginnings on the shore. Let us inquire, however, what the passage from water to dry land actually implied. This has been briefly discussed in a previous article (on Evolution), but the subject is one of great interest and importance.

Difficulties and Results of the Transition from Water to Land.

Leaving the water for dry land implied a loss in freedom of movement, for the terrestrial animal is primarily restricted to the surface of the earth. Thus it became essential that movements should be very rapid and very precise, needs with which we may associate the acquisition of fine cross-striped, quickly contracting muscles, and also, in time, their multiplication into very numerous separate engines. We exercise fifty-four muscles in the half-second that elapses between raising the heel of our foot in walking and planting it firmly on the ground again. Moreover, the need for rapid precisely controlled movements implied an improved nervous system, for the brain was a movement-controlling organ for ages before it did much in the way of thinking. The transition to terra firma also involved a greater compactness of body, so that there should not be too great friction on the surface. An animal like the jellyfish is unthinkable on land, and the elongated bodies of some land animals like centipedes and snakes are specially adapted so that they do not "sprawl." They are exceptions that prove the rule.

Getting on to dry land meant entering a kingdom where the differences between day and night, between summer and winter are more felt than in the sea. This made it advantageous to have protections against evaporation and loss of heat and other such dangers. Hence a variety of ways in which the surface of the body acquired a thickened skin, or a dead cuticle, or a shell, or a growth of hair, and so forth. In many cases there is an increase of the protection before the winter sets in, e.g. by

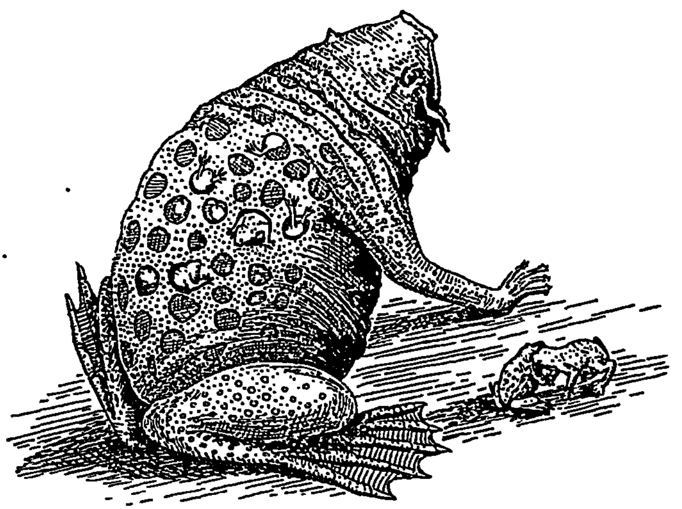
Photo: W. S. Berridge.

WOOLLY OPOSSUM CARRYING HER FAMILY.

One of the young ones is clinging to its mother and has its long prehensile tail coiled round hers.

growing thicker fur or by accumulating a layer of fat below the skin.

But the thickening or protection of the skin involved a partial or total loss of the skin as a respiratory surface. There is more oxygen available on dry land than in the water, but it is not so readily captured. Thus we see the importance of moist internal surfaces for capturing the oxygen which has been drawn into the interior of the body into some sort of lung. A unique solution was offered by Tracheate Arthropods, such as Peripatus, Centipedes, Millipedes, and Insects, where the air is carried to every hole and corner of the body by a ramifying system of air-tubes or tracheæ. In most animals the blood goes to the air, in insects the air goes to the blood. In the Robber-Crab, which has migrated from the shore inland, the dry air is absorbed by vascular tufts growing under the shelter of the gill-cover.



SURINAM TOAD (*PIPA AMERICANA*) WITH YOUNG ONES HATCHING OUT OF LITTLE POCKETS ON HER BACK.

The problem of disposing of eggs or young ones is obviously much more difficult on land than in the water. For the water offers an immediate cradle, whereas on the dry land there were many dangers, e.g. of drought, extremes of temperature, and hungry sharp-eyed enemies, which had to be circumvented. So we find all manner of ways in which land animals hide their eggs or their young ones in holes and nests, on herbs and on trees. Some carry their young ones about after they are born, like the Surinam toad and the kangaroo, while others have prolonged the period of ante-natal life during which the young ones develop in safety within their mother, and in very intimate partnership with her in the case of the placental mammals. It is very interesting to find that the pioneer animal called Peripatus, which bridges the gap between worms and insects, carries its young for almost a year before birth.

Enough has been said to show that the successive conquests of the dry land had great evolutionary results. It is hardly too much to say that the invasion which the Amphibians led was the beginning of better brains, more controlled activities, and higher expressions of family life.

VI. THE AIR

There are no animals thoroughly aerial, but many insects spend much of their adult life in the free air, and the swift hardly pauses in its flight from dawn to dusk of the long summer day, alighting only for brief moments at the nest to deliver insects to the young. All the active life of bats certainly deserves to be called aerial.

The air was the last haunt of life to be conquered, and it is interesting to inquire what the conquest implied. (1) It meant transcending the radical difficulty of terrestrial life which confines the creatures of the dry land to moving on one plane, the surface of the earth. But the power of flight brought its possessors back to the universal freedom of movement which water animals enjoy. When we watch a sparrow rise into the air just as the cat has completed her stealthy stalking, we see that flight implies an enormous increase of safety. (2)

[illegible]

[illegible caption]

powerful muscles, and are supported, like a fan, by ribs of chitin, which may be accompanied by air-tubes, blood-channels, and nerves. The insect's body is lightly built and very perfectly aërated, and the principle of the insect's flight is *the extremely* rapid striking of the air by means of the lightly built *elastic* wings. Many an insect has over two hundred strokes of its wings in one *second*. Hence, in many cases, the familiar hum, comparable on a small scale to that produced by the rapidly revolving blades of an aeroplane's propeller. For a short distance a bee can outfly a pigeon, but *few insects can fly far*, and they are easily blown away or blown back by the wind. Dragon-flies and bees may be cited as examples of insects that often fly for two or three miles. But this is exceptional, and the usual shortness of insect flight is an important fact for man since it limits the range of insects like house-flies and mosquitoes which are vehicles of typhoid fever and malaria respectively. The most primitive insects (spring-tails and bristle-tails) show no trace of wings, while fleas and lice have become secondarily wingless. It is interesting to notice that some insects only fly once in their lifetime, namely, in connection with mating. The evolution of the insect's wing remains quite obscure, but it is probable that insects could run, leap, and parachute before they could actually fly.

The extinct Flying Dragons or Pterodactyls had their golden age in the Cretaceous era, after which they disappeared, leaving no descendants. A fold of skin was spread out from the sides of the body by the enormously elongated outermost finger (usually regarded as corresponding to our little finger); it was continued to the hind-legs and thence to the tail.

[illegible] of a brilliant experiment. (a) The crowning advantage was the possibility of migrating, of [illegible] the [illegible] and the severe winter and of [illegible] by going quickly from one country to another and sometimes almost [illegible] the globe. There are not many acquisitions that have meant more to their possessors than the power of flight. It was a key opening the doors of a new freedom.

The problem of flight, as has been said in a previous chapter, has been solved four times, and the solution has been different in each case. The four solutions are those offered by insects, extinct Pterodactyls, birds, and bats. Moreover, as has been pointed out, there have been numerous attempts at flight which remain glorious failures, notably the flying fishes, which take a great leap and hold their pectoral fins taut; the Flying Tree-Toad, whose webbed fingers and toes form a parachute; the Flying Lizard (*Draco volans*), which has its skin pushed out on five or six greatly elongated mobile ribs; and various "flying" mammals, e.g. Flying Phalangers and Flying Squirrels, which take great swooping leaps from tree to tree.

The wings of an insect are hollow flattened sacs which grow out from the upper parts of the sides of the second and third rings of the region called the thorax. They are worked by

It is unlikely that the Pterodactyls could fly far, for they have at most a weak keel on their breastbone; on the other hand, some of them show a marked fusion of dorsal vertebræ, which, as in flying birds, must have served as a firm fulcrum for the stroke of the wings. The quaint creatures varied from the size of a sparrow up to a magnificent spread of 15–20 feet from tip to tip of the wings. They were the largest of all flying creatures.

The bird's solution of the problem of flight, which will be discussed separately, is centred in the feather, which forms a coherent vane for striking the air. In Pterodactyl and bat the wing is a web-wing or patagium, and a small web is to be seen on the front side of the bird's wing. But the bird's patagium is unimportant, and the bird's wing is on an evolutionary tack of its own—a fore-limb transformed for bearing the feathers of flight. Feathers are in a general way comparable to the scales of reptiles, but only in a general way, and no transition stage is known between the two. Birds evolved from a bipedal Dinosaur stock, as has been noticed already, and it is highly probable that they began their ascent by taking running leaps along the ground, flapping their scaly fore-limbs, and balancing themselves in kangaroo-like fashion with an extended tail. A second chapter was probably an arboreal apprenticeship, during which they made a fine art of parachuting—a persistence of which is to be seen in the pigeon "gliding" from the dovecot to the ground. It is in birds that the mastery of the air reaches its climax, and the mysterious "sailing" of the albatross and the vulture is surely the most remarkable locomotor triumph that has ever been achieved. Without any apparent stroke of the wings, the bird sails for half an hour at a time with the wind and against the wind, around the ship and in majestic spirals in the sky, probably taking advantage of currents of air of different velocities, and continually changing energy of position into energy of motion as it sinks, and energy of motion into energy of position as it rises. It is interesting to know that some dragon-flies are also able to "sail."

ALBATROSS: A CHARACTERISTIC PELAGIC BIRD OF THE SOUTHERN SEA.

It may have a spread of wing of over 11 feet from tip to tip. It is famous for its extraordinary power of "sailing" round the ship without any apparent strokes of its wings.

The web-wing of bats involves much more than the fore-arm. The double fold of skin begins on the side of the neck, passes along the front of the arm, skips the thumb, and is continued over the elongated palm-bones and fingers to the sides of the body again, and to the hind-legs, and to the tail if there is a tail. It is interesting to find that the bones of the bat's skeleton tend to be lightly built as in birds, that the breastbone has likewise a keel for the better

A. PROTECTIVE COLORATION OR CAMOUFLAGING, GIVING ANIMALS A GARMENT OF INVISIBILITY

At the foot of the plate is a Nightjar, with plumage like bark and withering leaves; to the right, resting on a branch, is shown a Chameleon in a green phase amid green surroundings; the insects on the reeds are Locusts; while a green Frog, merged into its surroundings, rests on a leaf near the centre at the top of the picture.

B. ANOTHER EXAMPLE OF PROTECTIVE COLORATION OR CAMOUFLAGE.

A shore scene showing Trout in the pool almost invisible against their background. The Stone Curlews, both adult and young, are very inconspicuous among the stones on the beach.

insertion of the pectoral muscles, and that there is a solidifying of the vertebræ of the back, affording as in birds a firm basis for the wing action. Such similar adaptations to similar needs, occurring in animals not nearly related to one another, are called "convergences," and form a very interesting study. In addition to adaptations which the bat shares with the flying bird, it has many of its own. There are so many nerve-endings on the wing, and often also on special skin-leaves about the ears and nose, that the bat flying in the dusk does not knock against branches or other obstacles. Some say that it is helped by the echoes of its high-pitched voice, but there is no doubt as to its exquisite tactility. That it usually produces only a single young one at a time is a clear adaptation to flight, and similarly the sharp, mountain-top-like cusps on the back teeth are adapted in insectivorous bats for crunching insects.

Whether we think of the triumphant flight of birds, reaching a climax in migration, or of the marvel that a creature of the earth—as a mammal essentially is—should evolve such a mastery of the air as we see in bats, or even of the repeated but splendid failures which parachuting animals illustrate, we gain an impression of the insurgence of living creatures in their characteristic endeavour after fuller well-being.

We have said enough to show how well adapted many animals are to meet the particular difficulties of the haunt which they tenant. But difficulties and limitations are ever arising afresh, and so one fitness follows on another. It is natural, therefore, to pass to the frequent occurrence of protective resemblance, camouflage, and mimicry—the subject of the next article.

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IV

THE STRUGGLE FOR EXISTENCE

ANIMAL AND BIRD MIMICRY AND DISGUISE

§ 1

FOR every animal one discovers when observing carefully, there must be ten unseen. This is partly because many animals burrow in the ground or get in underneath things and into dark corners, being what is called cryptozoic or elusive. But it is partly because many animals put on disguise or have in some way acquired a garment of invisibility. This is very common among animals, and it occurs in many forms and degrees. The reason why it is so common is because the struggle for existence is often very keen, and the reasons why the struggle for existence is keen are four. First, there is the tendency to over-population in many animals, especially those of low degree. Second, there is the fact that the scheme of nature involves nutritive chains or successive incarnations, one animal depending upon another for food, and all in the long run on plants; thirdly, every vigorous animal is a bit of a hustler, given to insurgence and sticking out his elbows. There is a fourth great reason for the struggle for existence, namely, the frequent changefulness of the physical environment, which forces animals to answer back or die; but the first three reasons have most to do with the very common assumption of some sort of disguise. Even when an animal is in no sense a weakling, it may be very advantageous for it to be inconspicuous when it is resting or when it is taking care of its young. Our problem is the evolution of elusiveness, so far at least as that depends on likeness to surroundings, on protective resemblance to other objects, and in its highest reaches on true mimicry.

Many animals living on sandy places have a light-brown colour, as is seen in some lizards and snakes. The green lizard is like the grass and the green tree-snake is inconspicuous among the branches. The spotted leopard

THE PRAYING MANTIS (*MANTIS RELIGIOSA*).

A very voracious insect with a quiet, unobtrusive appearance. It holds its formidable forelegs as if in the attitude of prayer; its movements are very slow and stealthy, and there is a suggestion of a leaf in the fore-wing. But there is no reason to credit the creature with conscious guile!

is suited to the interrupted light of the forest, and it is sometimes hard to tell where the jungle ends and the striped tiger begins. There is no better case than the hare or the partridge sitting a few yards off on the ploughed field. Even a donkey grazing in the dusk is much more readily heard than seen.

Colour permanently like that of Surroundings.

The experiment has been made of tethering the green variety of Praying Mantis on green herbage, fastening them with silk threads. They escape the notice of birds. The same is true when the brown variety is tethered on withered herbage. But if the green ones are put on brown plants, or the brown ones on green plants, the birds pick them off. Similarly, out of 300 chickens in a field, 240 white or black and therefore conspicuous, 60 spotted and inconspicuous, 24 were soon picked off by crows, but only one of these was spotted. This was not the proportion that there should have been if the mortality had been fortuitous. There is no doubt that it often pays an animal to be like its habitual surroundings, like a little piece of scenery if the animal is not moving. It is safe to say that in process of time wide departures from the safest coloration will be wiped out in the course of Nature's ceaseless sifting.

But we must not be credulous, and there are three cautions to be borne in mind. (1) An animal may be very like its surroundings without there being any protection implied. The arrow-worms in the sea are as clear as glass, and so are many open-sea animals. But this is because their tissues are so watery, with a specific gravity near that of the salt water. And the invisibility does not save them, always or often, from being swallowed by larger animals that gather the harvest of the sea. (2) Among the cleverer animals it looks as if the creature sometimes sought out a spot where it was most inconspicuous. A spider may place itself in the middle of a little patch of lichen, where its self-effacement is complete. Perhaps it is more comfortable as well as safer to rest in surroundings the general colour of which is like that of the animal's body.

Photo: A. A. White.

THE VARIABLE MONITOR (VARANUS).

The monitors are the largest of existing lizards, the Australian species represented in the photograph attaining a length of four feet. It has a brown colour with yellow spots, and in spite of its size it is not conspicuous against certain backgrounds, such as the bark of a tree.

PROTECTIVE COLORATION: A WINTER SCENE IN NORTH SCANDINAVIA.

Showing Variable Hare, Willow Grouse, and Arctic Fox, all white in winter and inconspicuous against the snow. But the white dress is also the dress that is physiologically best, for it loses least of the animal heat.

(3) The fishes that live among the coral-reefs are startling in their brilliant coloration, and there are many different patterns. To explain this it has been suggested that these fishes are so safe among the mazy passages and endless nooks of the reefs, that they can well afford to wear any colour that suits their constitution. In some cases this may be true, but naturalists who have put on a diving suit and walked about among the coral have told us that each kind of fish is particularly suited to some particular place, and that some are suited for midday work and others for evening work. Sometimes there is a sort of Box and Cox arrangement by which two different fishes utilise the same corner at different times.

§ 2

Gradual Change of Colour.

The common shore-crab shows many different colours and mottlings, especially when it is young. It may be green or grey, red or brown, and so forth, and it is often in admirable adjustment to the colour of the rock-pool where it is living. Experiments, which require extension, have shown that when the crab has moulted, which it has to do very often when it is young, the colour of the new shell tends to harmonise with the general colour of the rocks and seaweed. How this is brought about, we do not know. The colour does not seem to change till the next moult, and not then unless there is some reason for it. A full-grown shore-crab is well able to look after itself, and it is of interest to notice, therefore, that the variety of coloration is mainly among the small individuals, who have, of course, a much less secure position. It is possible, moreover, that the resemblance to the surroundings admits of more successful hunting, enabling the small crab to take its victim unawares.

Professor Poulton's experiments with the caterpillars of the small tortoise-shell butterfly showed that in black surroundings the pupæ tend to be darker, in white surroundings lighter, in gilded boxes golden; and the same is true in other cases. It appears that the surrounding colour affects the caterpillars through the skin during a sensitive period—the twenty hours

SEASONAL COLOUR-CHANGE: A SUMMER SCENE IN NORTH SCANDINAVIA.
Showing a brown Variable Hare, Willow Grouse, and Arctic Fox, all inconspicuous in their coloration when seen in their natural surroundings.

immediately preceding the last twelve hours of the larval state. The result will tend to make the quiescent pupæ less conspicuous during the critical time of metamorphosis. The physiology of this sympathetic colouring remains obscure.

The ptarmigan moults three times in the year. Its summer plumage is rather grouse-like above, with a good deal of rufous brown; the back becomes much more grey in autumn; almost all the feathers of the winter plumage are white. That is to say, they develop without any pigment and with numerous gas-bubbles in their cells. Now there can be no doubt that this white winter plumage makes the ptarmigan very inconspicuous among the snow. Sometimes one comes within a few feet of the crouching bird without seeing it, and this garment of invisibility may save it from the hungry eyes of golden eagles.

Seasonal Change of Colouring.

Similarly the brown stoat becomes the white ermine, mainly by the growth of a new suit of white fur, and the same is true of the mountain hare. The ermine is all white except the black tip of its tail; the mountain hare in its winter dress is all white save the black tips of its ears. In some cases, especially in the mountain hare, it seems that individual hairs may turn white, by a loss of pigment, as may occur in man. According to Metchnikoff, the wandering amœboid cells of the body, called phagocytes, may creep up into the hairs and come back again with microscopic burdens of pigment. The place of the pigment is taken by gas-bubbles, and that is what causes the whiteness. In no animals is there any white *pigment*; the white *colour* is like that of snow or foam, it is due to the complete reflection of the light from innumerable minute surfaces of crystals or bubbles.

The mountain hare may escape the fox the more readily because its whiteness makes it so inconspicuous against a background of snow; and yet, at other times, we have seen the creature standing out like a target on the dark moorland. So it cuts both ways. The ermine has almost no enemies except the gamekeeper, but its winter whiteness may help it to sneak upon its victims, such as grouse or rabbit, when

there is snow upon the ground. In both cases, however, the probability is that the constitutional rhythm which leads to white hair in winter has been fostered and fixed for a reason quite apart from protection. The fact is that for a warm-blooded creature, whether bird or mammal, the physiologically best dress is a white one, for there is less radiation of the precious animal heat from white plumage or white pellage than from any other colour. The quality of warm-bloodedness is a prerogative of birds and mammals, and it means that the body keeps an almost constant temperature, day and night, year in and year out. This is effected by automatic internal adjustments which regulate the supply of heat, chiefly from the muscles, to the loss of heat, chiefly through the skin and from the lungs. The chief importance of this internal heat is that it facilitates the smooth continuance of the chemical processes on which life depends. If the temperature falls, as in hibernating mammals (whose warm-bloodedness is imperfect), the rate of the vital process is slowed down—sometimes dangerously. Thus we see how the white coat helps the life of the creature.

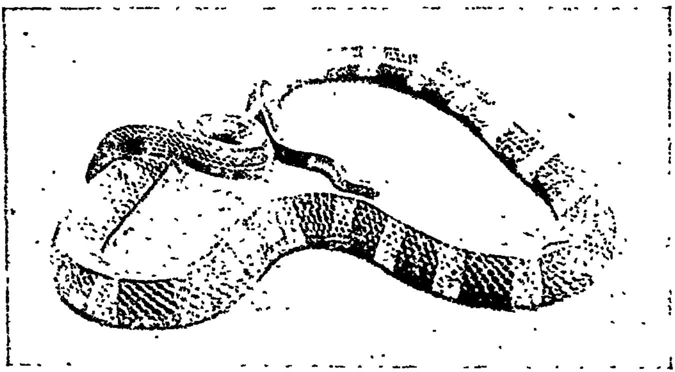


Photo: W. S. Berridge, F.Z.S.

BANDED KRAIT: A VERY POISONOUS SNAKE WITH ALTERNATING YELLOW AND DARK BANDS.

It is very conspicuous and may serve as an illustration of warning coloration. Perhaps, that is to say, its striking coloration serves as an advertisement, impressing other creatures with the fact that the Banded Krait should be left alone. It is very unprofitable for a snake to waste its venom on creatures it does not want.

§ 3

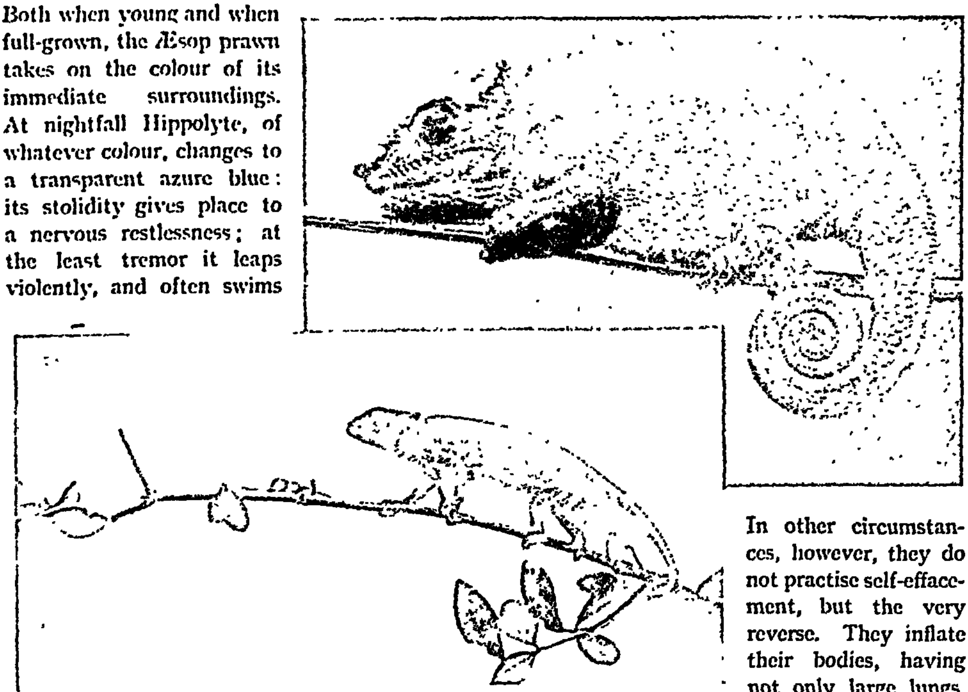
Bony flat-fishes, like plaice and sole, have a remarkable power of adjusting their hue and pattern to the surrounding gravel and sand, so that it is difficult to find them even when we know that they are there. It must be admitted that they are also very quick to get a sprinkling of sand over their upturned side, so that only the eyes are left showing. But there is no doubt as to the exactness with which they often adjust themselves to be like a little piece of the substratum on which they lie; they will do this within limits in experimental conditions when they are placed on a quite artificial floor. As these fishes are very palatable and are much sought after by such enemies as cormorants and otters, it is highly probable that their power of self-effacement often saves their life. And it may be effected within a few minutes, in some cases within a minute.

Rapid Colour-change.

In these self-effacing flat-fishes we know with some precision what happens. The adjustment of colour and pattern is due to changes in the size, shape, and position of mobile pigment-cells (chromatophores) in the skin. But what makes the pigment-cells change? The fact that a blind flat-fish does not change its colour gives us the first part of the answer. The colour and the pattern of the surroundings must affect the eye. The message travels by the optic nerve to the brain; from the brain, instead of passing down the spinal cord, the message travels down the chain of sympathetic ganglia. From these it passes along the nerves which come out of the spinal cord and control the skin. Thus the message reaches the colour-cells in the skin, and before you have carefully read these lines the flat-fish has slipped on its Gyges ring and become invisible.

The same power of rapid colour-change is seen in cuttlefishes, where it is often an expression of nervous excitement, though it sometimes helps to conceal. It occurs with much subtlety in the Æsop prawn, Hippolyte, which may be brown on a brown seaweed, green on sea-lettuce or sea-grass, red on red seaweed, and so on through an extensive repertory. "According

to the nature of the background," Professor Gamble writes, "so is the mixture of the pigments compounded so as to form a close reproduction both of its colour and its pattern. A sweep of the shrimp net detaches a battalion of these sleeping prawns, and if we turn the motley into a dish and give a choice of seaweed, each variety after its kind will select the one with which it agrees in colour, and vanish. Both when young and when full-grown, the Æsop prawn takes on the colour of its immediate surroundings. At nightfall Hippolyte, of whatever colour, changes to a transparent azure blue: its stolidity gives place to a nervous restlessness; at the least tremor it leaps violently, and often swims actively from one food-plant to another. This blue fit lasts till daybreak, and is then succeeded by the prawn's diurnal tint." Thus, Professor Gamble continues, the colour of an animal may express a nervous rhythm.



Photos: W. S. Berridge, F.Z.S.

THE WARTY CHAMELEON.

The upper photograph shows the Warty Chameleon inflated and conspicuous. At another time, however, with compressed body and adjusted coloration, the animal is very inconspicuous. The lower photograph shows the sudden protrusion of the very long tongue on a fly.

The highest level at which rapid colour-change occurs is among lizards, and the finest exhibition of it is among the chameleons.

The Case of Chameleons.

These quaint creatures are characteristic of Africa; but they occur also in Andalusia, Arabia, Ceylon, and Southern India. They are adapted for life on trees, where they hunt insects with great deliberateness and success. The protrusible tongue, ending in a sticky club, can be shot out for about seven inches in the common chameleon. Their hands and feet are split so that they grip the branches firmly, and the prehensile tail rivals a monkey's. When they wish they can make themselves very slim, contracting the body from side to side, so that they are not very readily seen. In other circumstances, however, they do not practise self-effacement, but the very reverse. They inflate their bodies, having not only large lungs, but air-sacs in connection with them. The throat bulges; the body sways from side to side; and the creature expresses its sentiments in a hiss. The power of colour-change is very remarkable, and depends partly on the contraction and expansion of the colour-cells (chromatophores) in the under-skin (or dermis) and partly on close-packed refractive granules and crystals of a waste-product called guanin. The repertory of possible colours in the common chameleon is greater than in any other animal except the Æsop prawn. There is a legend of a chameleon which was brown in a brown box, green in a green box, and blue in a blue box,

and died when put into one lined with tartan; and there is no doubt that one and the same animal has a wide range of colours. The so-called "chameleon" (*Anolis*) of North America

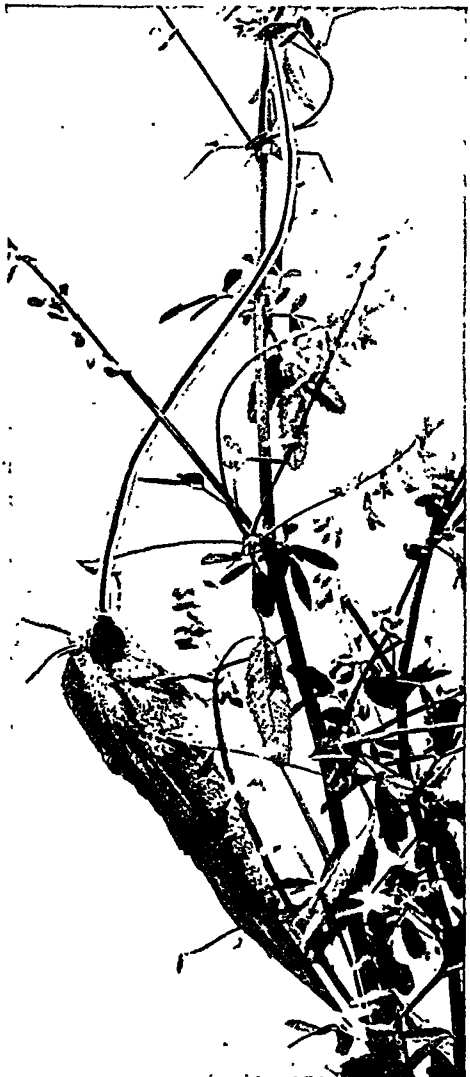


Photo: J. J. Ward, F.E.S.

PROTECTIVE RESEMBLANCE.

Hawk Moth, settled down on a branch, and very difficult to detect as long as it remains stationary. Note its remarkable sucking tongue, which is about twice the length of its body. The tongue can be quickly coiled up and put safely away beneath the lower part of the head.

is so sensitive that a passing cloud makes it change its emerald hue.

There is no doubt that a chameleon may make itself more inconspicuous by changing its colour, being affected by the play of light on its eyes. A bright-green hue is often seen on those that are sitting among strongly illumined green leaves. But the colour also changes with the time of day and with the animal's moods. A sudden irritation may bring about a rapid change; in other cases the transformation comes about very gradually. When the colour-change expresses the chameleon's feelings it might be compared to blushing, but that is due to an expansion of the arteries of the face, allowing more blood to get into the capillaries of the under-skin. The case of the chameleon is peculiarly interesting because the animal has two kinds of tactics—self-effacement on the one hand and bluffing on the other. There can be little doubt that the power of colour-change sometimes justifies itself by driving off intruders. Dr. Cyril Crossland observed that a chameleon attacked by a fox-terrier "turned round and opened its great pink mouth in the face of the advancing dog, at the same time rapidly changing colour, becoming almost black. This ruse succeeded every time, the dog turning off at once." In natural leafy surroundings the startling effect would be much greater—a sudden throwing off of the mantle of invisibility and the exposure of a conspicuous black body with a large red mouth.

§ 4

Likeness to other things.

Dr. H. O. Forbes tells of a flat spider which presents a striking resemblance to a bird's dropping on a leaf. Years after he first found it he was watching in a forest in the Far East when his eye fell on a leaf before him which had been blotched by a bird. He wondered idly why he had not seen for so long another specimen of the bird-dropping spider (*Ornithoscatoides decipiens*), and drew the leaf towards him. Instantaneously he got a characteristic sharp nip; it was the spider after all! Here the colour-resemblance was enhanced by a form-resemblance.

But why should it profit a spider to be like a bird-dropping? Perhaps because it thereby escapes attention; but there is another possibility. It seems that some butterflies, allied to our Blues, are often attracted to excrementitious material, and the spider Dr. Forbes observed had actually caught its victim. This is

WHEN ONLY A FEW DAYS OLD, YOUNG BITTERN BEGIN TO STRIKE THE SAME ATTITUDE AS THEIR PARENTS, THRUSTING THEIR BILLS UPWARDS AND DRAWING THEIR BODIES UP SO THAT THEY RESEMBLE A BUNCH OF REEDS.

The soft browns and blue greens harmonise with the dull sheaths of the young reeds; the nestling bittern is thus completely camouflaged.

borne out by a recent observation by Dr. D. G. H Carpenter, who found a Uganda bug closely resembling a bird-dropping on sand. The bug actually settled down on a bird-dropping on sand, and caught a blue butterfly which came to feed there!

Some of the walking-stick insects, belonging to the order of crickets and grasshoppers (Orthoptera), have their body elongated and narrow, like a thin dry branch, and they have a way of sticking out their limbs at abrupt and diverse angles, which makes the resemblance to twigs very close indeed. Some of these quaint insects rest through the day and have the remarkable habit of putting themselves into a sort of kataleptic state. Many creatures turn stiff when they get a shock, or pass suddenly into new surroundings, like some of the sand-hoppers when we lay them on the palm of our hand; but these twig-insects put themselves into this strange state. The body is rocked from side to side for a short time, and then it stiffens. An advantage may be that even if they were surprised by a bird or a lizard, they will not be able to betray themselves by even a tremor. Disguise is perfected by a remarkable habit, a habit which leads us to think of a whole series of different ways of lying low and saying nothing which are often of life-preserving value. The top end of the series is seen when a fox plays 'possum.

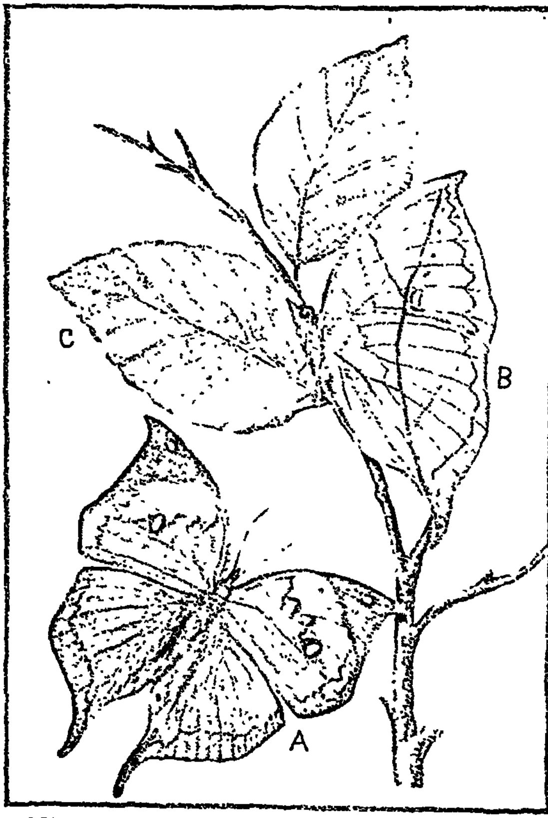
The leaf-butterfly *Kallima*, conspicuously coloured on its upper surface, is like a withered leaf when it settles down and shows the underside of its wings. Here, again, there is precise form-resemblance, for the nervures on the wings are like the midrib and side veins on a leaf, and the touch of perfection is given in the presence of whitish spots which look exactly like the discolorations produced by lichens on leaves. An old entomologist, Mr. Jenner Weir, confessed that he repeatedly pruned off a caterpillar on a bush in mistake for a superfluous twig, for many brownish caterpillars fasten themselves by their

posterior claspers and by an invisible thread of silk from their mouth, and project from the branch at a twig-like angle. An insect may be the very image of a sharp prickle or a piece of soft moss; a spider may look precisely like a tiny knob on a branch or a fragment of lichen; one of the sea-horses (*Phyllopteryx*) has frond-like tassels on various parts of its body, so that it looks extraordinarily like the seaweed among which it lives. In a few cases, e.g. among spiders, it has been shown that animals with a special protective resemblance to something else seek out a position where this resemblance tells, and there is urgent need for observations bearing on this selection of environment.

§ 5

Mimicry in the true sense.

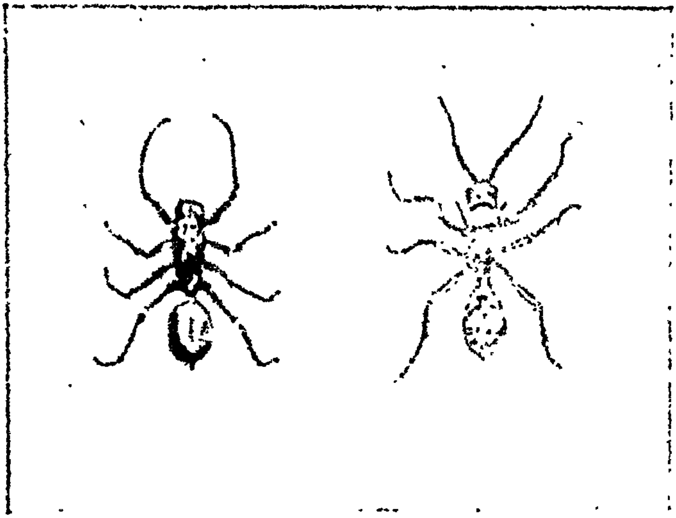
It sometimes happens that in one and the same place there are two groups of animals not very nearly related which are "doubles" of one another. Investigation shows that the members of the one group, *always in the majority*, are in some way specially protected, e.g. by being unpalatable. They are the "mimicked." The members of the other group, *always in the minority*, have not got the special protection possessed by the others. They are the "mimickers," though the resemblance is not, of course, associated with any *conscious* imitation. The theory is that the mimickers live on the reputation of the mimicked. If the mimicked are left alone by birds because they have a reputation for unpalatability, or because they are able to sting, the mimickers survive —although they are palatable and stingless. They succeed, not through any virtue of their own, but because of their resemblance to the mimicked, for whom they are mistaken. There are many cases of mimetic resemblance so striking and so subtle that it seems impossible to doubt that the thing works; there are other cases which are rather far-fetched, and may be somewhat of the nature of coincidences. Thus, although Mr. Bates tells us that he repeatedly shot humming-bird moths in mistake for humming-birds, we cannot think that this is a good illustration of mimicry. What is needed for many cases is what is forthcoming for some, namely, experimental evidence, e.g. that the unpalatable mimicked butterflies are left in relative peace while similar palatable butterflies are persecuted. It is also necessary to show that the mimickers do actually consort with the mimicked. Some beetles and moths are curiously wasp-like, which may be a great advantage; the common drone-fly is superficially like a small bee; some



DEAD-LEAF BUTTERFLY (*KALLIMA INACHIS*) FROM INDIA.

It is conspicuous on its upper surface, but when it settles down on a twig and shows the underside of its wings it is practically invisible. The colouring of the under surface of the wings is like that of a withering leaf; there are spots like fungus spots; and the venation of the wings suggests the midrib and veins of the leaf. A, showing upper surface; B, showing under surface; C, a leaf.

harmless snakes are very like poisonous species; and Mr. Wallace maintained that the powerful "friar-birds" of the Far East are mimicked by the weak and timid orioles. When the



PROTECTIVE RESEMBLANCE BETWEEN A SMALL SPIDER (*on the left*) AND AN ANT (*on the right*)

[illegible] the spider to be like an ant. It will be noticed [illegible] whereas the ant has three pairs of legs and a pair of feelers.

model is unpalatable or repulsive or dangerous, and the mimic the reverse, the mimicry is called "Batesian" (after Mr Bates), but there is another kind of mimicry called Müllerian (after Fritz Müller) where the mimic is also unpalatable. The theory in this case is that the mimicry serves as mutual assurance, the members of the ring getting on better by consistently presenting the same appearance, which has come to mean to possible enemies a signal, *Noli me tangere* ("Leave me alone"). There is nothing out of the question in this theory, but it requires to be taken in a critical spirit. It leads us to think of "warning colours," which are the very opposite of the disguises which we are now studying. Some creatures like skunks, magpies, coral-snakes, cobras, brightly coloured tree-frogs are obtrusive rather than elusive, and the theory of Alfred Russel Wallace was that the flaunting conspicuousness serves as a useful advertisement, impressing itself on the memories of inexperienced enemies, who soon learn to leave creatures with "warning colours" alone. In any case it is plain that an animal which is as safe as a wasp or a coral-snake can afford to wear any suit of clothes it likes.

Masking. The episode in Scottish history called "The Walking Wood of Birnam," when the advancing troop masked their approach by cutting down branches of the trees, has had its counterpart in many countries. But it is also enacted on the seashore. There are many kinds of crabs that put on disguise with what looks like deliberateness. The sand-crab takes a piece of seaweed, nibbles at the end of it, and then rubs it on the back of the carapace or on the legs so that it fixes to the bristles. As the seaweed continues to live, the crab soon has a little garden on its back which masks the crab's real nature. It is most effective camouflaging, but if the crab continues to grow it has to moult, and that means losing the disguise. It is then necessary to make a new one. The crab must have on the shore something corre-

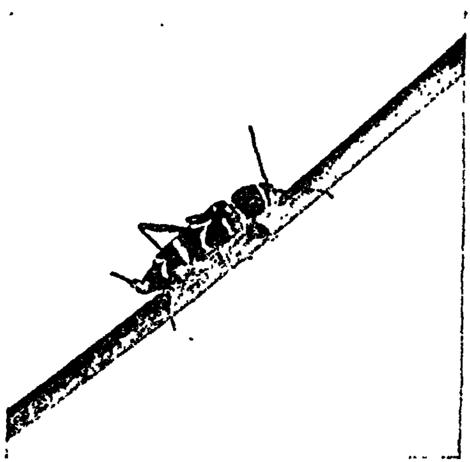


Photo: J. J. Ward, F.E.S.

THE WASP BEETLE, WHICH, WHEN MOVING AMONGST THE BRANCHES, GIVES A WASP-LIKE IMPRESSION.

sponding to a reputation; that is to say, other animals are clearly or dimly aware that the crab is a voracious and combative creature. How useful to the crab, then, to have its appearance cloaked by a growth of innocent seaweed, or sponge, or zoophyte. It will enable the creature to sneak upon its victims or to escape the attention of its own enemies.

If a narrow-beaked crab is cleaned artificially it will proceed to clothe itself again; the habit has become instinctive; and it must be admitted that while a particular crab prefers a particular kind of seaweed for its dress, it will cover itself with unsuitable and even conspicuous material, such as pieces of coloured cloth, if nothing better is available. The disguise differs greatly, for one crab is masked by a brightly coloured and unpalatable sponge densely packed with flinty needles; another cuts off the tunic of a sea-squirt and throws it over its shoulders; another trundles about a bivalve shell. The facts recall the familiar case of the hermit-crab, which protects its soft tail by tucking it into the empty shell of a periwinkle or a whelk or some other sea-snail, and that case leads on to the elaboration known as commensalism, where the hermit-crab fixes sea-anemones on the back of its borrowed house. The advantage here is beyond that of masking, for the sea-anemone can sting, which is a useful quality in a partner. That this second advantage may become the main one is evident in several cases where the sea-anemone is borne, just like a weapon, on each of the crustacean's great claws. Moreover, as the term commensalism (eating at the same table) suggests, the partnership is *mutually* beneficial. For the sea-anemone is carried about by the hermit-crab, and it doubtless gets its share of crumbs from its partner's frequent meals. There is a very interesting sidelight on the mutual benefit in the case of a dislodged sea-anemone which sulked for a while and then waited in a state of preparedness until a hermit-crab passed by and touched it. Whereupon the sea-anemone gripped and slowly worked itself up on to the back of the shell.

HERMIT-CRAB WITH PARTNER SEA-ANEMONES.

Hermit-crabs hide their soft tail in the shell of a whelk or some other sea snail. But some hermit crabs place sea-anemones on the back of their borrowed shell The sea-anemones mask the hermit-crab and their tentacles can sting. As for the sea-anemones, they are carried about by the hermit-crab and they get crumbs from its table. This kind of mutually beneficial external partnership is called commensalism, i.e. eating at the same table

§ 6

Other kinds of Elusiveness.

There are various kinds of disguise which are not readily classified. A troop of cuttlefish swimming in the sea is a beautiful sight. They keep time with one another in their movements and they show the same change of colour almost at the same moment. They are suddenly attacked, however, by a small shark, and then comes a simultaneous discharge of sepia from their inkbags. There are clouds of ink in the clear water, for, as Professor Hickson puts it, the cuttlefishes have thrown dust in the eyes of their enemies. One can see a newborn cuttlefish do this a minute after it escapes from the egg.

Very beautiful is the way in which many birds, like our common chaffinch, disguise the outside of their nest with moss and lichen and other trifles felted together, so that the cradle is as inconspicuous as possible. There seems to be a touch of art in fastening pieces of spider's web on the outside of a nest!

How curious is the case of the tree-sloth of South American forests, that walks slowly, back downwards, along the undersides of the branches, hanging on by its long, curved fingers and toes. It is a nocturnal animal, and therefore not in special danger, but when it is resting

during the day it is almost invisible because its shaggy hair is so like certain lichens and other growths on the branches. But the protective resemblance is enhanced by the presence of a green alga, which actually lives on the surface of the sloth's hairs — an alga like the one that makes tree-stems and gate-posts green in damp weather.

There is no commoner sight in the early summer than the cuckoo-spit on the grasses and herbage by the wayside. It is conspicuous and yet it is said to be left severely alone by almost all creatures. In some way it must be a disguise. It is a sort of soap made by the activity of small frog-hoppers while they are still in the wingless larval stage, before they begin to hop. The insect pierces with its sharp mouth-parts the skin of the plant and sucks in sweet sap which by and by overflows over its body. It works its body up and down many times, whipping in air, which mixes with the sugary sap, reminding one of how "whipped egg" is made. But along with the sugary sap and the air, there is a little ferment from the food-canal and a little wax from glands on the skin, and the four things mixed together make a kind of soap which lasts through the heat of the day.

Photo: G. P. Duffus.

CUCKOO-SPIT.

The white mass in the centre of the picture is a soapy froth which the young frog hopper makes, and within which it lies safe both from the heat of the sun and almost all enemies. After sojourning for a time in the cuckoo-spit, the frog-hopper becomes a winged insect.

There are many other modes of disguise besides those which we have been able to illustrate. Indeed, the biggest fact is that there are so many, for it brings us back to the idea that life is not an easy business. It is true, as Walt Whitman says, that animals do not sweat and whine about their condition; perhaps it is true, as he says, that not one is unhappy over the whole earth. But there is another truth, that this world is not a place for the unlit lamp and the ungirt loin, and that when a creature has not armour or weapons or cleverness it must find some path of safety or go back. One of these paths of safety is disguise, and we have illustrated its evolution.

V

THE ASCENT OF MAN

§ 1

NO one thinks less of Sir Isaac Newton because he was born as a very puny infant, and no one should think less of the human race because it sprang from a stock of arboreal mammals. There is no doubt as to man's apartness from the rest of creation when he is seen at his best—"a little lower than the angels, crowned with glory and honour." "What a piece of work is a man! How noble in reason! How infinite in faculty! in form and moving how express and admirable! in action how like an angel! in apprehension so like a God." Nevertheless, all the facts point to his affiliation to the stock to which monkeys and apes also belong. Not, indeed, that man is descended from any living ape or monkey; it is rather that he and they have sprung from a common ancestry—are branches of the same stem. This conclusion is so momentous that the reasons for accepting it must be carefully considered. They were expounded with masterly skill in Darwin's *Descent of Man* in 1871—a book which was but an expansion of a chapter in *The Origin of Species* (1859).

Anatomical Proof of Man's Relationship with a Simian Stock.

The anatomical structure of man is closely similar to that of the anthropoid apes — the gorilla, the orang, the chimpanzee, and the gibbon. Bone for bone, muscle for muscle, blood-vessel for blood-vessel, nerve for nerve, man and ape agree. As the conservative anatomist, Sir Richard Owen, said, there is between them "an all-pervading similitude of structure." Differences, of course, there are, but they are not momentous except man's big brain, which may be three times as heavy as that of a gorilla. The average human brain weighs about 48 ounces; the gorilla brain does not exceed 20 ounces at its best. The capacity of the human skull is never less than 55 cubic inches; in the orang and the chimpanzee the figures are 26 and $27\frac{1}{2}$ respectively. We are not suggesting that the most distinctive features of man are such as can be measured and weighed, but it is important to notice that the main seat of his mental powers is physically far ahead of that of the highest of the anthropoid apes.

Photo: New York Zoological Park.

CHIMPANZEE, SITTING.

The head shows certain facial characteristics, e.g. the beetling eyebrow ridges, which were marked in the Neanderthal race of men. Note the shortening of the thumb and the enlargement of the big toe.

Man alone is thoroughly erect after his infancy is past; his head weighted with the heavy brain does not droop forward as the ape's does; with his erect attitude there is perhaps to be associated his more highly developed vocal organs. Compared with an anthropoid ape, man has a bigger and more upright forehead, a less protrusive face region, smaller cheek-bones and eyebrow ridges, and more uniform teeth. He is almost

unique in having a chin. Man plants the sole of his foot flat on the ground, his big toe is usually in a line with the other toes, and he has a better heel than any monkey has. The change in the shape of the head is to be thought of in connection with the enlargement of the brain, and also in connection with the natural reduction of the muzzle region when the hand was freed from being an organ of support and became suited for grasping the food and conveying it to the mouth.

Everyone is familiar in man's clothing with traces of the past persisting in the present, though their use has long since disappeared. There are buttons on the back of the waist of the morning coat to which the tails of the coat used to be fastened up, and there are buttons, occasionally with buttonholes, at the wrist which were once useful in turning up the sleeve. The same is true of man's body, which is a veritable museum of relics. Some anatomists have made out a list of over a hundred of these *vestigial* structures, and though this number is perhaps too high, there is no doubt that the list is long. In the inner upper corner of the eye there is a minute tag—but larger in some races than in others—which is the last dwindling relic of the third eyelid, used in cleaning the front of the eye, which most mammals possess in a large and well-developed form. It can be easily seen, for instance, in ox and rabbit. In man and in monkeys it has become a useless vestige, and the dwindling must be associated with the fact that the upper eyelid is much more mobile in man and monkeys than in the other mammals. The vestigial third eyelid in man is enough of itself to prove his relationship with the mammals, but it is only one example out of many. Some of these are discussed in the article dealing with the human body, but we may mention the vestigial muscles going to the ear-trumpet, man's dwindling counterpart of the skin-twitching muscle which we see a horse use when he jerks a fly off his flanks, and the short tail which in the seven-weeks-old human embryo is actually longer than the leg. Without committing ourselves to a belief in the entire uselessness of the vermiform appendix, which grows out as a blind alley at the junction of the small intestine with the large, we are safe in saying that it is a dwindling structure—the remains of a blind gut which must have been capacious and useful in ancestral forms. In

Photo: New York Zoological Park.

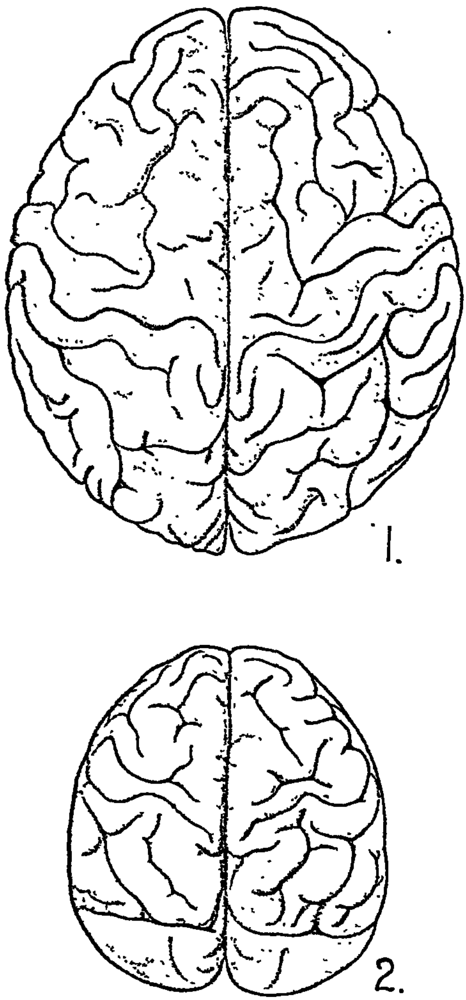
CHIMPANZEE, ILLUSTRATING WALKING POWERS.

Note the great length of the arms and the relative shortness of the legs.

some mammals, like the rabbit, the blind gut is the bulkiest structure in the body, and bears the vermiform appendix at its far end. In man the appendix alone is left, and it tells its tale. It is interesting to notice that it is usually longer in the orang than in man, and that it is very variable, as dwindling structures tend to be. One of the unpleasant expressions of this variability is the liability to go wrong: hence appendicitis. Now these vestigial structures are, as Darwin said, like the unsounded, i.e. functionless, letters in words, such as the *o* in "leopard," the *b* in "doubt," the *g* in "reign." They are of no use, but they tell us something of the history of the words. So do man's vestigial structures reveal his pedigree. They must have an historical or evolutionary significance. No other interpretation is possible.

Some men, oftener than women, show on the inturned margin of the ear-trumpet or pinna, a little conical projection of great interest. It is

a vestige of the tip of the pointed ear of lower mammals, and it is well named *Darwin's point.* It was he who described it as a "surviving symbol of the stirring times and dangerous days of man's animal youth."



SURFACE-VIEW OF THE BRAINS OF MAN (1) AND CHIMPANZEE (2).

The human brain is much larger and heavier, more dome like, and with much more numerous and complicated convolutions.

§ 2

The everyday functions of the human body are practically the same as those of the anthropoid ape, and similar disorders are common to both. Monkeys may be infected with certain microbes to which man is peculiarly liable, such as the bacillus of tuberculosis. Darwin showed that various human gestures and facial expressions have their counterparts in monkeys. The sneering curl of the upper lip, which tends to expose the canine tooth, is a case in point, though it may be seen in many other mammals besides monkeys—in dogs, for instance, which are at some considerable distance from the simian branch to which man's ancestors belonged.

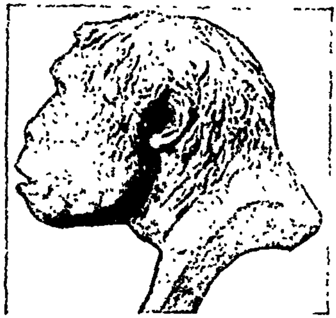
Physiological Proof of Man's Relationship with a Simian Stock.

When human blood is transfused into a dog or even a monkey, it behaves in a hostile way to the other blood, bringing about a destruction of the red blood corpuscles. But when it is transfused into a chimpanzee there is an harmonious mingling of the two. This is a very literal demonstration of man's blood-relationship with the higher apes. But there is a finer form of the same experiment. When the blood-fluid (or serum) of a rabbit, which has had human blood injected into it, is mingled with human blood, it forms a cloudy precipitate. It forms almost as marked a precipitate when it is mingled with the blood of an anthropoid ape. But when it is mingled with the blood of an American monkey there is only a slight clouding after a considerable time and no actual precipitate. When it is added to the blood of one of the distantly related "half-monkeys" or lemurs there is no reaction or only a very weak one. With the blood of mammals off the simian line altogether there is no reaction at all. Thus, as a distinguished anthropologist, Professor Schwalbe, has said: "We have in this not only a proof of the literal blood-relationship between man and apes, but the degree of relationship with the different main groups of apes can be determined beyond possibility of mistake." We can imagine how this modern line of experiment would have delighted Darwin.

In his individual development, man does in some measure climb up his own genealogical tree. Stages in the development of the body during its nine months of ante-natal life are closely similar to stages in the development of the anthropoid embryo. Babies born in times of famine or siege are sometimes, as it were, imperfectly finished, and

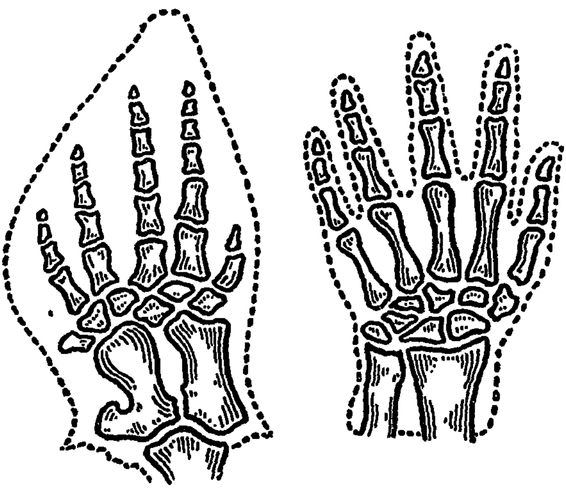
Embryological Proof of Man's Relationship with a Simian Stock.

Photo: New York Zoological Park.
SIDE-VIEW OF CHIMPANZEE'S HEAD.
(Compare with opposite picture.)



After a model by J. H. McGregor.
PROFILE VIEW OF HEAD OF PITHECANTHROPUS, THE JAVA APE MAN, RECONSTRUCTED FROM THE SKULL CAP.

sometimes have what may be described as monkeyish features and ways. A visit to an institution for the care of children who show arrested, defective, or disturbed development leaves one sadly impressed with the risk of slipping down the rungs of the steep ladder of evolution; and even in adults the occurrence of serious nervous disturbance, such as "shell-shock," is sometimes marked by relapses to animal ways. It is a familiar fact that a normal baby reveals the past in its surprising power of grip, and the careful experiments of Dr. Louis Robinson showed that an infant three weeks old could support its own weight for over two minutes, holding on to a horizontal bar. "In many cases no sign of distress is evinced and no cry uttered, until the grasp begins to give way." This persistent grasp probably points back to the time when the baby had to cling to its arboreal mother. The human tail is represented in the adult by a fusion of four or five vertebræ forming the "coccyx" at the end of the backbone, and is normally concealed beneath the flesh, but in the embryo the tail projects freely and is movable. Up to the sixth month of the ante-natal sleep the body is covered, all but the palms and soles, with longish hair (the lanugo), which usually disappears before birth. This is a stage in the normal development, which is reasonably interpreted as a recapitulation of a stage in the racial evolution. We draw this inference when we find that the unborn offspring of an almost hairless whale has an abundant representation of hairs; we must draw a similar inference in the case of man.



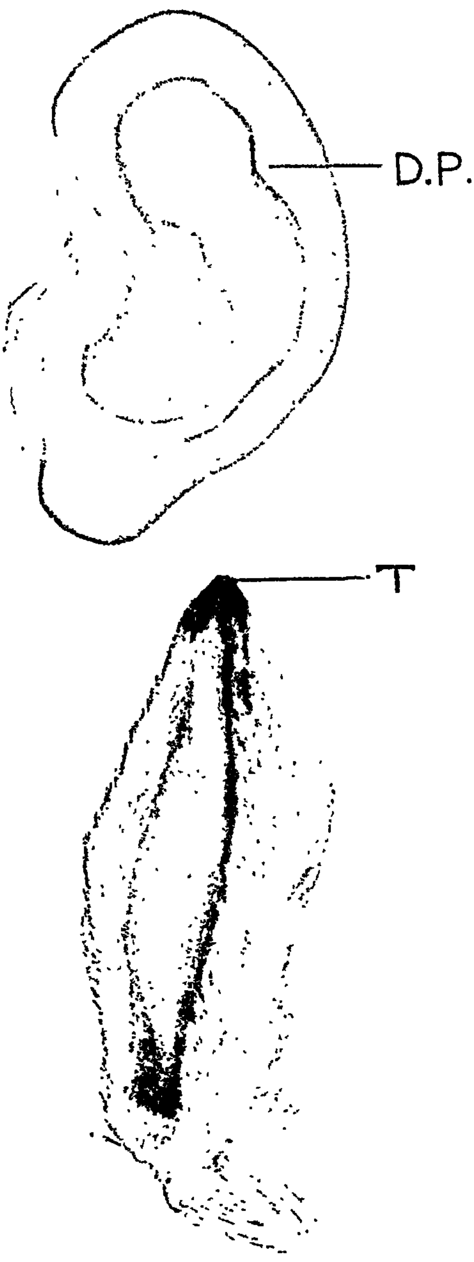
THE FLIPPER OF A WHALE AND THE HAND OF A MAN.
In the bones and in their arrangement there is a close resemblance in the two cases, yet the outcome is very different. The multiplication of finger joints in the whale is a striking feature.

It must be noticed that there are two serious errors in the careless statement often made that man in his development is at one time like a little fish, at a later stage like a little reptile, at a later stage like a little primitive mammal, and eventually like a little monkey. The first error here is that the comparison should be

made with *embryo-fish*, *embryo-reptile*, *embryo-mammal*, and so on. It is in the making of the embryos that the great resemblance lies. When the human embryo shows the laying down of the essential vertebrate characters, such as brain and spinal cord, then it is closely comparable to the embryo of a lower vertebrate at a similar stage. When, at a subsequent stage, its heart, for instance, is about to become a four-chambered mammalian heart, it is closely comparable to the heart of, let us say, a turtle, which never becomes more than three-chambered. The point is that in the making of the organs of the body, say brain and kidneys, the embryo of man pursues a path closely corresponding to the path followed by the embryos of other backboned animals lower in the scale, but at successive stages it parts company with these, with the lowest first and so on in succession. A human embryo is never like a little reptile, but the developing organs pass through stages which very closely resemble the corresponding stages in lower types which are in a general way ancestral.

The second error is that every kind of animal, man included, has from the first a certain individuality, with peculiar characteristics which are all its own. This is expressed by the somewhat difficult word *specificity*, which just means that every species is itself and no other. So in the development of the human embryo, while there are close resemblances to the embryos of apes, monkeys, other mammals, and even, at earlier stages still, to the embryos of reptile and fish, it has to be admitted that we are dealing from first to last with a human embryo with peculiarities of its own.

Every human being begins his or her life as a single cell—a fertilised egg-cell, a treasure-house of all the ages. For in this living microcosm, only a small fraction ($\frac{1}{125}$) of an inch in diameter, there is condensed—who can imagine how?—all the natural inheritance of man, all the legacy of his parentage, of his ancestry, of his long pre-human pedigree. Darwin called the pinhead brain of the ant the most marvellous atom of matter in the world, but the human ovum is more marvellous still. It has more possibilities in it than any other thing, yet without fertilisation it will die. The fertilised ovum divides and redivides; there results a ball



"DARWIN'S POINT" ON HUMAN EAR (MARKED D.P.)

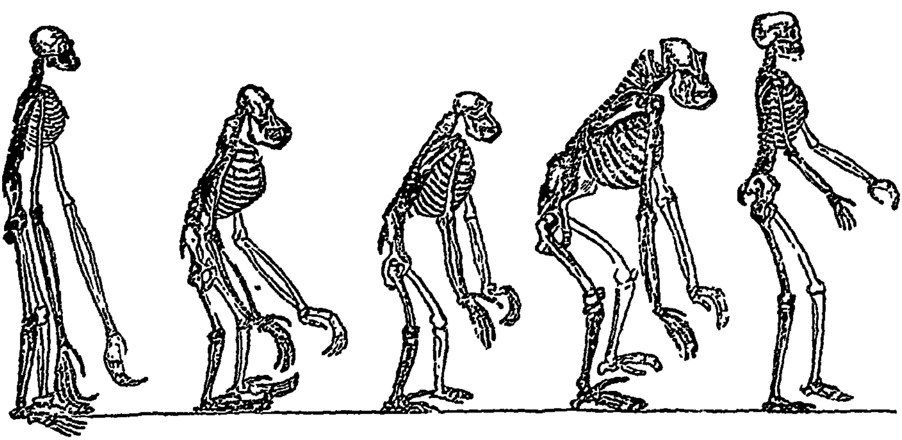
It corresponds to the tip (T) of the ear of an ordinary mammal, as shown in the hare's ear below. In the young orang the part corresponding to Darwin's point is still at the tip of the ear.

Photo: J. Russell & Sons.

PROFESSOR SIR ARTHUR KEITH, M.D., LL.D., F.R.S.

Conservator of the Museum and Hunterian Professor, Royal College of Surgeons of England. One of the foremost living anthropologists and a leading authority on the antiquity of man.

of cells and a sack of cells; gradually division of labour becomes the rule; there is a laying down of nervous system and food-canal, muscular system and skeleton, and so proceeds what is learnedly called differentiation. Out of the apparently simple there emerges the obviously complex. As Aristotle observed more than two thousand years ago, in the developing egg of the hen there soon appears the beating heart! There is nothing like this in the non-living world. But to return to the developing human embryo, there is formed from and above the embryonic food-canal a skeletal rod, which is called the notochord. It thrills the imagination to learn that this is the only supporting axis that the lower orders of the backboned race possess. The curious thing is that it does not become the backbone, which is certainly one of the essential features of the vertebrate race. The notochord is the supporting axis of the pioneer backboned animals, namely the Lancelets and the Round-mouths (Cyclostomes), such as the Lamprey. They have no backbone in the strict sense, but they have this notochord. It can easily be dissected out in the lamprey—a long gristly rod. It is surrounded by a sheath which becomes the backbone of most fishes and of all higher animals. The interesting point is that although the notochord is only a vestige in the adults of these types, it is never absent from the embryo. It occurs even in man, a short-lived relic of the primeval supporting axis of the body. It comes and then it goes, leaving only minute traces in the adult. We cannot say that it is of any use, unless it serves as a stimulus to the development of its substitute,



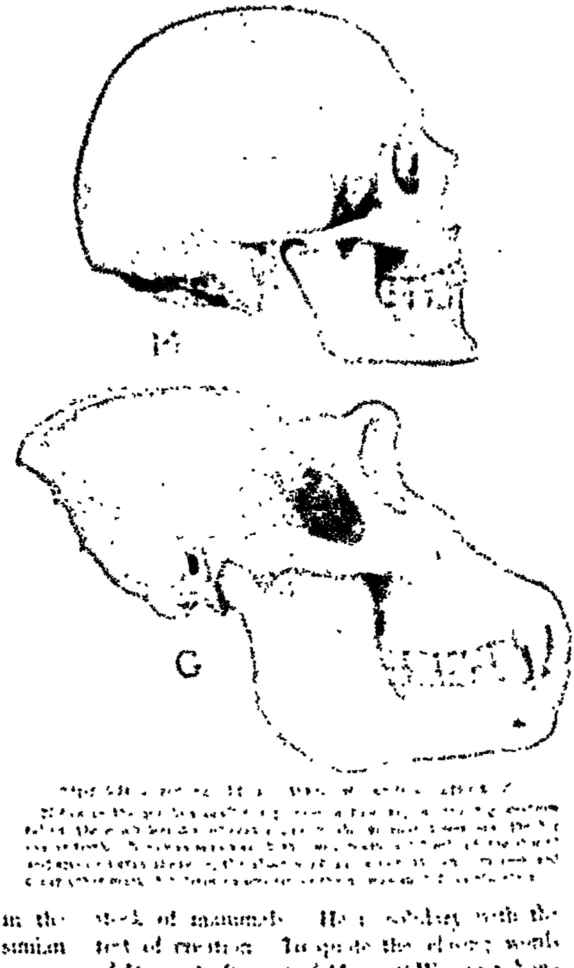
After T. H. Huxley (by permission of Messrs. Macmillan).

SKELETONS OF THE GIBBON, ORANG, CHIMPANZEE, GORILLA, MAN.

Photographically reduced from diagrams of the natural size (except that of the gibbon, which was twice as large as nature) drawn by Mr. Waterhouse Hawkins from specimens in the Museum of the Royal College of Surgeons.

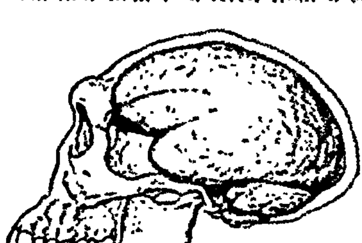
the backbone. It is only a piece of preliminary scaffolding, but there is no more eloquent instance of the living hand of the past.

One other instance must suffice of what Professor Keith calls the wonderful changes wrought in the dark of the antenatal period, which recapitulate in an abbreviated way the great evolutionary steps which were taken by man's ancestors "during the long night of the geological past." On the sides of the neck of the human embryo there are four pairs of slits, the "visceral clefts," openings from the beginning of the food canal to the surface. There is no doubt as to their significance. They correspond to the gill-slits of fishes and tadpoles. Yet in reptiles, birds, and mammals they have no connection with breathing, which is their function in fishes and amphibians. Indeed, they are not of any use at all except that the first becomes the Eustachian tube bearing the ear-passage into connection with the back of the mouth, and that the second and third have to do with the development of a curious organ called the thymus gland. Persistent, nevertheless, these gill-slits are, recalling even in man an aquatic ancestry of many millions of years ago.



[illegible]

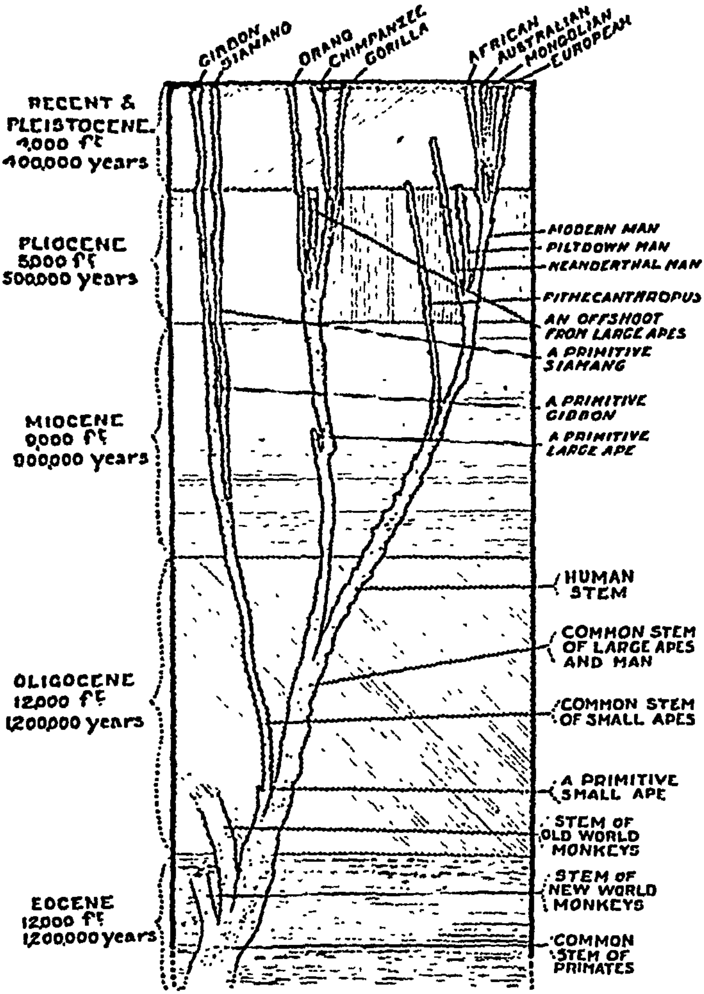
When all these lines of evidence are considered, they are seen to converge in the conclusion that man is derived from a simian stock of mammals. He is solidary with the rest of creation. To quote the closing words of Darwin's *Descent of Man*: "We must, however, acknowledge, as it seems to me, that man with all his noble qualities, with sympathy which feels for the most debased, with benevolence which extends not only to other men but to the humblest living creature, with his God-like intellect, which has penetrated into the movements and constitution of the solar system—with all these exalted powers—man still bears in his bodily frame the indelible stamp of his lowly origin." We should be clear that this view does not say more than that man sprang from a stock common to him and to the higher apes. Those who are repelled by the idea of man's derivation from a simian type should remember that the theory implies rather



THE SKULL AND BRAIN CASE OF PITHECANTHROPUS, THE JAVA APE-MAN, AS RESTORED BY J. H. McGREGOR FROM THE SCANTY REMAINS.

The restoration shows the low, retreating forehead and the prominent eyebrow ridges.

more than this, namely, that man is the outcome of a genealogy which has implied many millions of years of experimenting and sifting—the groaning and travailing of a whole creation. Speaking of man's mental qualities, Sir Ray Lankester says: "They justify the view that man forms a new departure in the gradual unfolding of Nature's predestined plan." In any case, we have to try to square our views with the facts, not the facts with our views, and while one of the facts is that man stands unique and apart, the other is that man is a scion of a progressive simian stock. Naturalists have exposed the pit whence man has been digged and the rock whence he has been hewn, but it is surely a heartening encouragement to know that it is an ascent, not a descent, that we have behind us. There is wisdom in Pascal's maxim: "It is dangerous to show man too plainly how like he is to the animals, without, at the same time, reminding him of his greatness. It is equally unwise to impress him with his greatness and not with his lowliness. It is worse to leave him in ignorance of both. But it is very profitable to recognise the two facts."



SUGGESTED GENEALOGICAL TREE OF MAN AND ANTHROPOID APES.
From Sir Arthur Keith; the lettering to the right has been slightly simplified.

§ 3

The facts of anatomy, physiology, and embryology, of which we have given illustrations, all point to man's affiliation with the order of monkeys and apes. To this order is given the name Primates, and our first and second question must be when and whence the Primates began. The rock record answers the first question: the Primates emerged about the dawn of the Eocene era, when grass was beginning to cover the earth with a garment. Their ancestral home was in the north in both hemispheres, and then they migrated to Africa, India, Malay, and South America. In North America the Primates soon became extinct, and the same thing happened

Man's Pedigree.

later on in Europe. In this case, however, there was a repeopling from the South (in the Lower Miocene) and then a second extinction (in the Upper Pliocene) before man appeared. There is considerable evidence in support of Professor R. S. Lull's conclusion, that in Southern Asia, Africa, and South America the evolution of Primates was continuous since the first great southward migration, and there is, of course, an abundant modern representation of Primates in these regions to-day.

Photo: New York Zoological Park.

THE GIBBON IS LOWER THAN THE OTHER APES AS REGARDS ITS SKULL AND DENTITION, BUT IT IS HIGHLY SPECIALISED IN THE ADAPTATION OF ITS LIMBS TO ARBOREAL LIFE.

As to the second question: Whence the Primates sprang, the answer must be more conjectural. But it is a reasonable view that Carnivores and Primates sprang from a common Insectivore stock, the one order diverging towards flesh-eating and hunting on the ground, the other order diverging towards fruit-eating and arboreal habits. There is no doubt that the Insectivores (including shrews, tree-shrews, hedgehog, mole, and the like) were very plastic and progressive mammals.

What followed in the course of ages was the divergence of branch after branch from the main Primate stem. First there diverged the South American monkeys on a line of their own, and then the Old-World monkeys, such as the macaques and baboons. Ages passed and the main stem gave off (in the Oligocene period) the branch now represented by the small anthropoid apes—the gibbon and the siamang. Distinctly later there diverged the branch of the large anthropoid apes—the gorilla, the chimpanzee, and the orang. That left a generalised humanoid stock separated off from all monkeys and apes, and including the immediate precursors of man. When this sifting out of a generalised humanoid stock took place remains very uncertain, some authorities referring it to the Miocene, others to the early Pliocene. Some would estimate its date at half a million years ago, others at two millions! The fact is that questions of chronology do not as yet admit of scientific statement.

We are on firmer, though still uncertain, ground when we state the probability that it was in Asia that the precursors of man were separated off from monkeys and apes, and began to be terrestrial rather than arboreal. Professor Lull points out that Asia is nearest to the oldest known human remains (in Java), and that Asia was the seat of the most ancient civilisations and the original home of many domesticated animals and cultivated plants. The probability is that the cradle of the human race was in Asia.

At this point it will be useful to consider man's arboreal apprenticeship and how he became a terrestrial journeyman. Professor Wood Jones has worked out very convincingly the thesis that man had no direct four-footed ancestry, but that the Primate stock to which he belongs was from its first divergence arboreal. He maintains that the leading peculiarities of the immediate precursors of man were wrought out during a long arboreal apprenticeship. The first great gain of arboreal life on bipedal erect lines (not after the quadrupedal fashion of tree-sloths, for instance) was the emancipation of the hand. The foot became the supporting and branch-gripping member, and the hand was set free to reach upward, to hang on by, to seize the fruit,

Man's Arboreal Apprenticeship.

to lift it and hold it to the mouth, and to hug the young one close to the breast. The hand thus set free has remained plastic—a generalised, not a specialised member. Much has followed from man's "handiness."

The arboreal life had many other consequences. *It led to an increased freedom of movement of the thigh on the hip joint*, to muscular arrangements for balancing the body on the leg, to making the backbone a supple yet stable curved pillar, to a strongly developed collar-bone which is only found well-formed when the fore-limb is used for more than support, and to a power of "opposing" the thumb and the big toe to the other digits of the hand and foot—an obvious advantage for branch-gripping. But the evolution of a free hand made it possible to dispense with protrusive lips and gripping teeth. Thus *began the recession of the snout region*, the associated enlargement of the brain-box, and the bringing of the eyes to the front. The *overcrowding* of the teeth that followed the shortening of the snout was one of the taxes on progress of which modern man is often reminded in his dental troubles.

Another acquisition associated with arboreal life was a greatly increased power of turning the head from side to side—a mobility very important in locating sounds and in exploring with the eyes. Furthermore, there came about a flattening of the chest and of the back, and the movements of the midriff (or diaphragm) came to count for more in respiration than the movements of the ribs. The sense of touch came to be of more importance and the sense of smell of less; the part of the brain receiving tidings from hand and eye and ear came to predominate over the part for receiving olfactory messages. Finally, the need for carrying the infant about among the branches must surely have implied an intensification of family relations, and favoured the evolution of gentleness.

It may be urged that we are attaching too much importance to the arboreal apprenticeship, since many tree-loving animals remain to-day very innocent creatures. To this reasonable objection there are two answers, first that in its many acquisitions the arboreal evolution of the *humanoid* precursors of man prepared the way for the survival of a *human* type marked by a great step in brain-development; and second that the passage from the humanoid to the human was probably associated with *a return to mother earth.*

According to Professor Lull, to whose fine textbook, *Organic Evolution* (1917), we are much indebted, "climatic conditions in Asia in the Miocene or early Pliocene were such as to compel

Photo: New York Zoological Park.

THE ORANG HAS A HIGH ROUNDED SKULL AND A LONG FACE

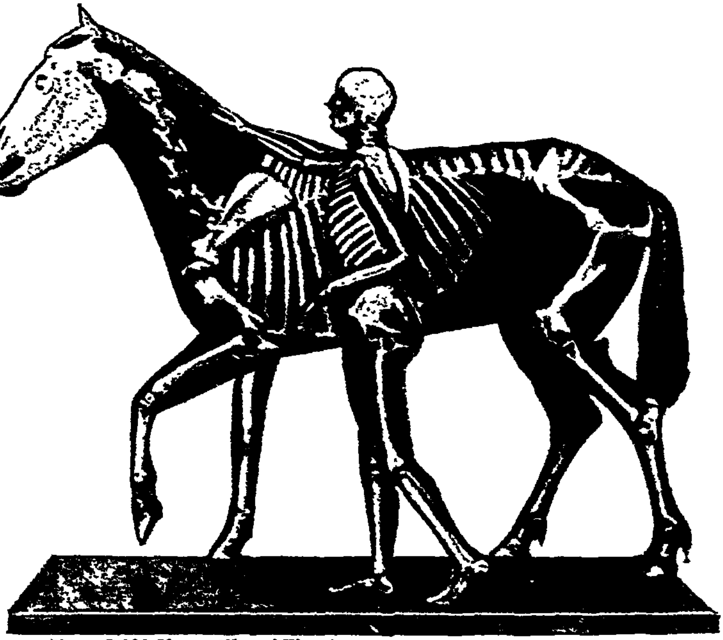


Photo: British Museum (Natural History).

COMPARISONS OF THE SKELETONS OF HORSE AND MAN.

"Bone for bone, the two skeletons are like one another, though man is a biped and the horse a quadruped. The backbone in man is mainly vertical; the backbone in the horse is horizontal except in the neck and the tail. Man's skull is mainly in a line with the backbone; the horse's at an angle to it. Both man and horse have seven neck vertebræ. Man has five digits on each limb; the horse has only one digit well developed on each limb.

the descent of the prehuman ancestor from the trees, a step which was absolutely essential to further human development." Continental elevation and consequent aridity led to a dwindling of the forests, and forced the ape-man to come to earth. "And at the last arose the man."

According to Lull, the descent from the trees was associated with the assumption of a more erect posture, with increased liberation and plasticity of the hand, with becoming a hunter, with experiments towards clothing and shelter, with an exploring habit, and with the beginning of communal life.

It is a plausible view that the transition from the humanoid to the human was effected by a discontinuous variation of considerable magnitude, what is nowadays called a *mutation*, and that it had mainly to do with the brain and the vocal organs. But given the gains of the arboreal apprenticeship, the stimulus of an enforced descent to terra firma, and an evolving brain and voice, we can recognise accessory factors which helped success to succeed. Perhaps the absence of great physical strength prompted reliance on wits; the prolongation of infancy would help to educate the parents in gentleness; the strengthening of the feeling of kinship would favour the evolution of family and social life—of which there are many anticipations at lower levels. There is much truth in the saying: "Man did not make society, society made man."

A continuation of the story will deal with the emergence of the primitive types of man and the gradual ascent of the modern species.

THE GORILLA, INHABITING THE FOREST TRACT OF THE GABOON IN AFRICA

A full-grown individual stands about [illegible] feet high. [illegible]

After a model by J. H. McGregor.

PROFILE VIEW OF THE HEAD OF PITHECANTHROPUS, THE JAVA APE-MAN—AN EARLY OFFSHOOT FROM THE MAIN LINE OF MAN'S ASCENT.

The animal remains found along with the skull-cap, thigh-bone, and two teeth of Pithecanthropus seem to indicate the Lower Pleistocene period, perhaps 500,000 years ago

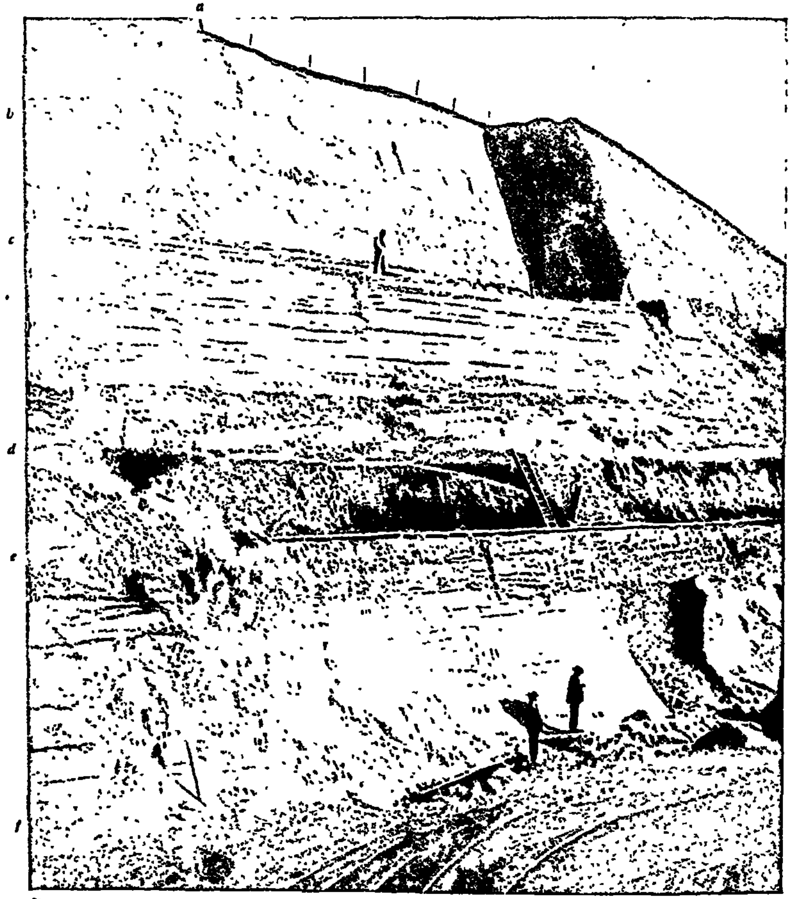
§ 4

Tentative Men.

So far the story has been that of the sifting out of a humanoid stock and of the transition to human kind, from the ancestors of apes and men to the man-ape, and from the man-ape to man. It looks as if the sifting-out process had proceeded further, for there were several human branches that did not lead on to the modern type of man.

1. The first of these is represented by the scanty fossil remains known as *Pithecanthropus erectus*, found in Java in fossiliferous beds which date from the end of the Pliocene or the beginning of the Pleistocene era. Perhaps this means half a million years ago, and the remains occurred along with those of some mammals which are now extinct. Unfortunately the remains of Pithecanthropus the Erect consisted only of a skull-cap, a thigh-bone, and two back teeth, so it is not surprising that experts should differ considerably in their interpretation of what was found. Some have regarded the remains as those of a large gibbon, others as those of a prehuman ape-man, and others as those of a primitive man off the main line of ascent. According to Sir Arthur Keith, Pithecanthropus was "a being human in stature, human in gait, human in all its parts, save its brain." The thigh-bone indicates a height of about 5 feet 7 inches, one inch less than the average height of the men of to-day. The skull-cap indicates a low, flat forehead, beetling brows, and a capacity about two-thirds of the modern size. The remains were found by Dubois, in 1894, in Trinil in Central Java.

2. The next offshoot is represented by the Heidelberg man (*Homo heidelbergensis*), discovered near Heidelberg in 1907 by Dr. Schoetensack. But the remains consisted only of a lower jaw and its teeth. Along with this relic were bones



Reproduced by permission from Osborn's "Men of the Old Stone Age."

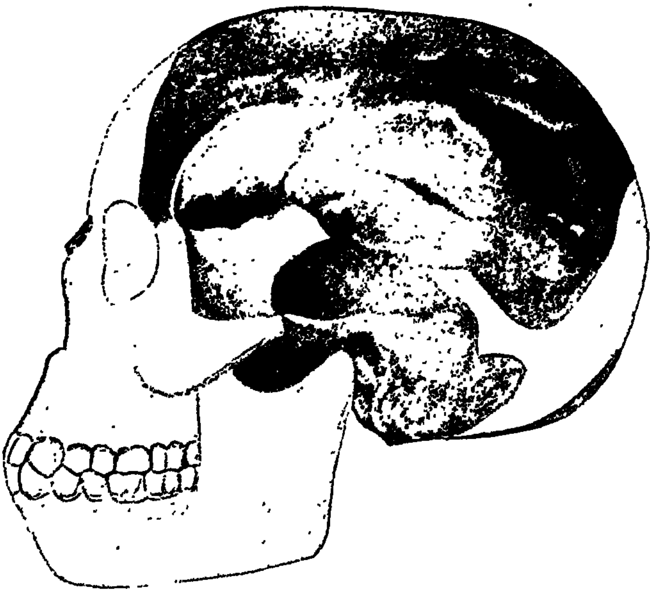
SAND-PIT AT MAUER, NEAR HEIDELBERG: DISCOVERY SITE OF THE JAW OF HEIDELBERG MAN.

a—b. "Newer loess," either of Third Interglacial or of Postglacial times.
b—c. "Older loess" (sandy loess), of the close of Second Interglacial times.
c—f. The "sands of Mauer."
d—e. An intermediate layer of clay.
The white cross (X) indicates the spot at the base of the "sands of Mauer" at which the jaw of Heidelberg was discovered.

of various mammals, including some long since extinct in Europe, such as elephant, rhinoceros, bison, and lion. The circumstances indicate an age of perhaps 300,000 years ago. There were also very crude flint implements (or coliths). But the teeth are human teeth, and the jaw seems transitional between that of an anthropoid ape and that of man. Thus there was no chin. According to most authorities the lower jaw from the Heidelberg sand-pit must be regarded as a relic of a primitive type off the main line of human ascent.

3. It was in all probability in the Pliocene that there took origin the Neanderthal species of man, *Homo neanderthalensis,* first known from remains found in 1856 in the Neanderthal ravine near Düsseldorf. According to some authorities Neanderthal man was living in Europe a quarter of a million years ago. Other specimens were afterwards found elsewhere, e.g. in Belgium ("the men of Spy"), in France, in Croatia, and at Gibraltar, so that a good deal is known of Neanderthal man. He was a loose-limbed fellow, short of stature and of slouching

gait, but a skilful artificer, fashioning beautifully worked flints with a characteristic style. He used fire; he buried his dead reverently and furnished them with an outfit for a long journey; and he had a big brain. But he had great beetling, ape-like eyebrow ridges and massive jaws, and he showed "simian characters swarming in the details of his structure." In most of the points in which he differs from modern man he approaches the anthropoid apes, and he must be regarded as a low type of man, off the main line. Huxley regarded the Neanderthal man as a low form of the modern type, but expert opinion seems to agree rather with the view maintained in 1864 by Professor William King of Galway, that the Neanderthal man represents a distinct species off the main line of ascent. He disappeared with apparent suddenness (like some aboriginal races to-day) about the end of the Fourth Great Ice Age; but there is evidence that before he ceased to be there had emerged a successor rather than a descendant—the modern man.



From the reconstruction by J. H. McGregor.

PILTDOWN SKULL. THE DARK PARTS ONLY ARE PRESERVED, NAMELY, PORTIONS OF THE CRANIAL WALLS AND THE NASAL BONES.

Some authorities include a canine tooth and part of the lower jaw which were found close by. The remains were found in 1912 in Thames gravels in Sussex, and are usually regarded as vastly more ancient than those of Neanderthal Man. It has been suggested that Piltdown Man lived 100,000 to 150,000 years ago, in the Third Interglacial period.

4. Another offshoot from the main line is probably represented by the Piltdown man, found in Sussex in 1912. The remains consisted of the walls of the skull, which indicate a large brain, and a high forehead without the beetling eyebrows of the Neanderthal man and Pithecanthropus. The "find" included a tooth and part of a lower jaw, but these perhaps belong to some ape, for they are very discrepant. The Piltdown skull represents the most ancient human remains as yet found in Britain, and Dr. Smith Woodward's establishment of a separate genus Eoanthropus expresses his conviction that the Piltdown man was off the line of the evolution of the modern type. If the tooth and piece of lower jaw belong to the Piltdown skull, then there was a remarkable combination of ape-like and human characters. As regards the brain, *inferred* from the skull-walls, Sir Arthur Keith says: "All the essential features of the brain of modern man are to be seen in the brain cast. There are some which must be regarded as primitive. There can be no doubt that it is built on exactly the same lines as our modern brains. A few minor alterations would make it in all respects a modern brain." "Although our knowledge of the human brain is limited—there are large areas to which we can assign no definite function—we may rest assured that a brain which was shaped in a mould so similar to our own was one which responded to the outside world as ours does. Piltdown man saw, heard, felt, thought, and dreamt much as we do still." And this was 150,000 years ago at a modern estimate, and some would say half a million.

There is neither agreement nor certainty as to the antiquity of man, except that the modern type was distinguishable from its collaterals hundreds of thousands of years ago. The

general impression left is very grand. In remote antiquity the Primate stem diverged from the other orders of mammals; it sent forth its tentative branches, and the result was a tangle of monkeys; ages passed and the monkeys were left behind, while the main stem, still probing its way, gave off the Anthropoid apes, both small and large. But they too were left behind, and the main line gave off other experiments—indications of which we know in Java, at Heidelberg, in the Neanderthal, and at Piltdown. None of these lasted or was made perfect. They represent *tentative* men who had their day and ceased to be, our predecessors rather than our ancestors. Still, the main stem goes on evolving, and who will be bold enough to say what fruit it has yet to bear!

After the restoration modelled by J. H. McGregor.

PILTDOWN MAN, PRECEDING NEANDERTHAL MAN, PERHAPS 100,000 TO 150,000 YEARS AGO.

Primitive Men.

Ancient skeletons of men of the modern type have been found in many places, e.g. Combe Capelle in Dordogne, Galley Hill in Kent, Cro-Magnon in Périgord, Mentone on the Riviera; and they are often referred to as "Cave-men" or "men of the Early Stone Age." They had large skulls, high foreheads, well-marked chins, and other features such as modern man possesses. They were true men at last—that is to say, like ourselves! The spirited pictures they made on the walls of caves in France and Spain show artistic sense and skill. Well-finished statuettes representing nude female figures are also known. The elaborate burial customs point to a belief in life after death. They made stone implements—knives, scrapers, gravers, and the like, of the type known as Palæolithic, and these show interesting gradations of skill and peculiarities of style. The "Cave-men" lived between the third and fourth Ice Ages, along with cave-bear, cave-lion, cave-hyæna, mammoth, woolly rhinoceros, Irish elk, and other mammals now extinct—taking us back to 30,000–50,000 years ago, and many would say much more. Some of the big-brained skulls of these Palæolithic cave-men show not a single feature that could be called primitive. They show teeth which in size and

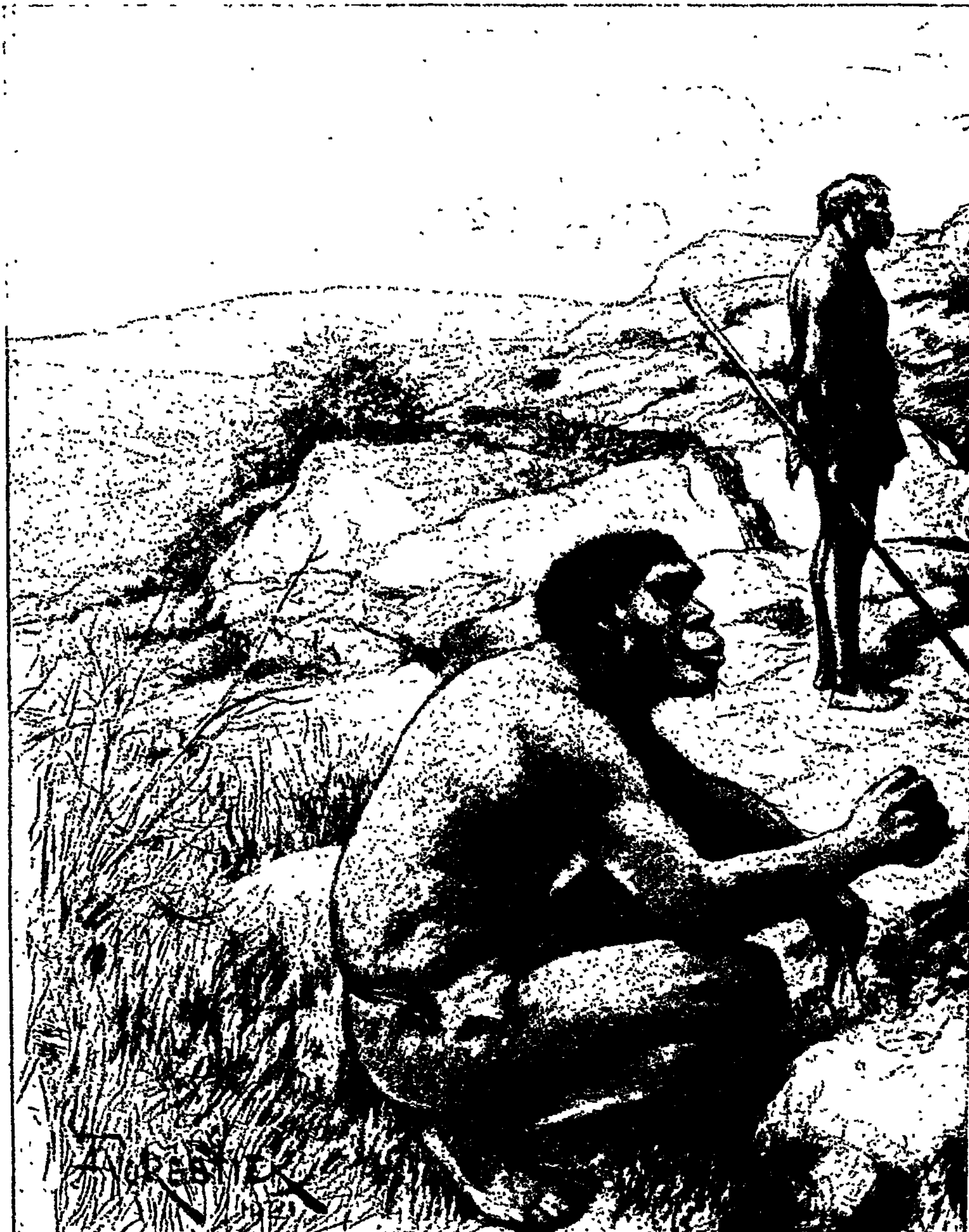
form are exactly the same as those of a thousand generations afterwards—and suffering from gumboil too! There seems little doubt that these vigorous Palæolithic Cave-men of Europe were living for a while contemporaneously with the men of Neanderthal, and it is possible that they directly or indirectly hastened the disappearance of their more primitive collaterals. Curiously enough, however, they had not themselves adequate lasting power in Europe, for they seem for the most part to have dwindled away, leaving perhaps stray present-day survivors in isolated districts. The probability is that after their decline Europe was repeopled by immigrants from Asia. It cannot be said that there is any inherent biological necessity for the decline of a vigorous race—many animal races go back for millions of years—but in mankind the historical fact is that a period of great racial vigour and success is often followed by a period of decline, sometimes leading to practical disappearance as a definite race. The causes of this waning remain very obscure—sometimes environmental, sometimes constitutional, sometimes competitive. Sometimes the introduction of a new parasite, like the malaria organism, may have been to blame.

After the restoration modelled by J. H. McGregor.

THE NEANDERTHAL MAN OF LA CHAPELLE-AUX-SAINTS.

The men of this race lived in Europe from the Third Interglacial period through the Fourth Glacial. They disappeared somewhat suddenly, being replaced by the Modern Man type, such as the Cromagnards. Many regard the Neanderthal Men as a distinct species.

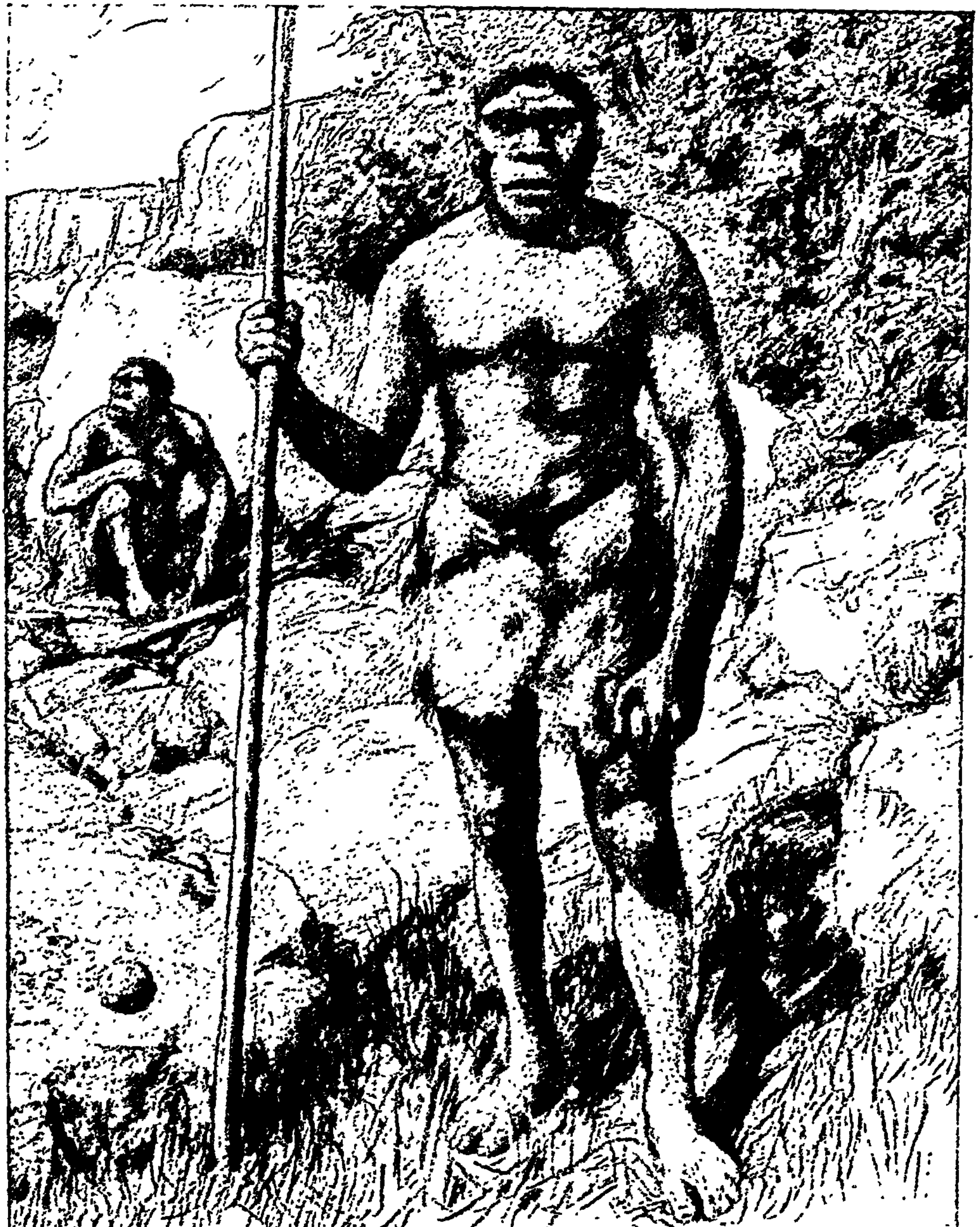
After the Ice Ages had passed, perhaps 25,000 years ago, the Palæolithic culture gave place to the Neolithic. The men who made rudely dressed but often beautiful stone implements were succeeded or replaced by men who made polished stone implements. The earliest inhabitants of Scotland were of this Neolithic culture, migrating from the Continent when the ice-fields of the Great Glaciation had disappeared. Their remains are often associated with the "Fifty-foot Beach" which, though now high and dry, was the seashore in early Neolithic days. Much is known about these men of the polished stones. They were hunters, fowlers, and fishermen; without domesticated animals or agriculture; short folk, two or three inches below the present standard; living an active strenuous life. Similarly, for the south, Sir Arthur Keith pictures for us a Neolithic community at Coldrum in Kent, dating from about 4,000 years ago—a few ticks of the geological clock. It consisted, in this case, of agricultural pioneers, men with large heads and big brains, about two inches shorter in stature than the modern British average (5 ft. 8 in.), with better teeth and broader palates than men have in these days



RESTORATION BY A. FORESTIER OF THE RHODESIAN

Attention may be drawn to the beetling eyebrow ridges, the projecting upper lip, the large eye-sockets, the well-poised head, the strong shoulders.

The figure in the right foreground, holding a staff, shows the erect attitude and the straight legs. His left hand holds a flint implement.



MAN WHOSE SKULL WAS DISCOVERED IN 1921.

The squatting figure to the left is crushing seeds with a stone, and a crusher is lying on the rock to his right.

On the right, behind the sitting figure, is seen the entrance to the cave. This new Rhodesian cave-man may be regarded as a southern representative of a Neanderthal race, or as an extinct type intermediate between the Neanderthal Men and the Modern Man type.

of soft food, with beliefs concerning life and death similar to those that swayed their contemporaries in Western and Southern Europe. Very interesting is the manipulative skill they showed on a large scale in erecting standing stones (probably connected with calendar-keeping and with worship), and, on a small scale, in making daring operations on the skull. Four thousand years ago is given as a probable date for that early community in Kent, but evidences of Neolithic man occur in situations which demand a much greater antiquity—perhaps 30,000 years. And man was not young then!

Photo: British Museum (Natural History).

SIDE VIEW OF A PREHISTORIC HUMAN SKULL DISCOVERED IN 1921 IN BROKEN HILL CAVE, NORTHERN RHODESIA.

Very striking are the prominent eyebrow ridges and the broad massive face. The skull looks less domed than that of modern man, but its cranial capacity is far above the lowest human limit. The teeth are interesting in showing marked rotting or "caries," hitherto unknown in prehistoric skulls. In all probability the Rhodesian man was an African representative of the extinct Neanderthal species hitherto known only from Europe.

We must open one more chapter in the thrilling story of the Ascent of Man—the Metal Ages, which are in a sense still continuing. Metals began to be used in the late Polished Stone (Neolithic) times, for there were always overlappings. Copper came first, Bronze second, and Iron last. The working of copper in the East has been traced back to the fourth millennium B.C., and there was also a very ancient Copper Age in the New World. It need hardly be said that where copper is scarce, as in Britain, we cannot expect to find much trace of a Copper Age.

The ores of different metals seem to have been smelted together in an experimental way by many prehistoric metallurgists, and bronze was the alloy that rewarded the combination of tin with copper. There is evidence of a more or less definite Bronze Age in Egypt and Babylonia, Greece and Europe.

It is not clear why iron should not have been the earliest metal to be used by man, but the Iron Age dates from about the middle of the second millennium B.C. From Egypt the usage spread through the Mediterranean region to North Europe, or it may have been that discoveries made in Central Europe, so rich in iron-mines, saturated southwards, following, for instance, the route of the amber trade from the Baltic. Compared with stone, the metals afforded much greater possibilities of implements, instruments, and weapons, and their discovery and usage had undoubtedly great influence on the Ascent of Man. Occasionally, however, on his descent.

Retrospect. Looking backwards, we discern the following stages: (1) The setting apart of a Primate stock, marked off from other mammals by a tendency to big brains, a free hand, gregariousness, and good-humoured talkativeness. (2) The divergence of marmosets and New World monkeys and Old World monkeys, leaving a stock—an anthropoid stock—common to the present-day and extinct apes and to mankind. (3) From this common stock the Anthropoid apes diverged, far from ignoble creatures, and a humanoid stock was set apart. (4) From the latter (we follow Sir Arthur Keith and other authorities) there arose what may be called, without disparagement, tentative or experimental men, indicated by Pithecanthropus "the Erect," the Heidelberg man, the Neanderthalers, and, best of all, the early men of the Sussex Weald—hinted at by the Piltdown skull. It matters little whether particular items are corroborated or disproved—e.g. whether the Heidelberg man came before or after the Neanderthalers—the general trend of evolution remains clear. (5) In any case, the result was

the evolution of *Homo sapiens, the man we are*—a quite different fellow from the Neanderthaler. (6) Then arose various stocks of primitive men, proving everything and holding fast to that which is good. There were the Palæolithic peoples, with rude stone implements, a strong vigorous race, but probably, in most cases, supplanted by fresh experiments. These may have arisen as shoots from the growing point of the old race, or as a fresh offshoot from more generalised members at a lower level. This is the eternal possible victory alike of aristocracy and democracy. (7) Palæolithic men were involved in the succession of four Great Ice Ages or Glaciations, and it may be that the human race owes much to the alternation of hard times and easy times—glacial and interglacial. When the ice-fields cleared off Neolithic man had his innings. (8) And we have closed the story, in the meantime, with the Metal Ages.

It seems not unfitting that we should at this point sound another note—that of the man of feeling. It is clear in William James's words: "Bone of our bone, and flesh of our flesh, are these half-brutish prehistoric brothers. Girdled about with the immense darkness of this mysterious universe even as we are, they were born and died, suffered and struggled. Given over to fearful crime and passion, plunged in the blackest ignorance, preyed upon by hideous and grotesque delusions, yet steadfastly serving the profoundest of ideals in their fixed faith that existence in any form is better than non-existence, they ever rescued triumphantly from the jaws of ever imminent destruction the torch of life which, thanks to them, now lights the world for us."

After the restoration modelled by J. H. McGregor.

A CROMAGNON MAN OR CROMAGNARD, REPRESENTATIVE OF A STRONG ARTISTIC RACE LIVING IN THE SOUTH OF FRANCE IN THE UPPER PLEISTOCENE, PERHAPS 25,000 YEARS AGO.

They seemed to have lived for a while contemporaneously with the Neanderthal Men, and there may have been interbreeding. Some Cromagnards probably survive, but the race as a whole declined, and there was repopulation of Europe from the East.

Given a variable stock spreading over diverse territory, we expect to find it splitting up into varieties, which may become steadied into races or incipient species. Thus we have races of hive-bees, "Italians," "Punics," and so forth; and thus there arose races of men. Certain types suited certain areas, and periods of in-breeding tended to make the distinctive peculiarities of each incipient race well-defined and stable.

Races of Mankind.

When the original peculiarities, say, of negro and Mongol, Australian and Caucasian, arose as brusque variations or "mutations," then they would have great staying power from generation to generation. They would not be readily swamped by intercrossing or averaged off. Peculiarities and changes of climate and surroundings, not to speak of other change-producing factors, would provoke fresh new departures from age to age, and so fresh racial ventures were made. Moreover, the occurrence of out-breeding when two races met, in peace or in war, would certainly serve to induce fresh starts. Very important in

Reproduced by permission from Osborn's "Men of the Old Stone Age."

PHOTOGRAPH SHOWING A NARROW PASSAGE IN THE CAVERN OF FONT-DE-GAUME ON THE BEUNE.

Throughout the cavern the walls are crowded with engravings; on the left wall, shown in the photograph, are two painted bison. In the great gallery there may be found not less than eighty figures—bison, reindeer, and mammoths. A specimen of the last is reproduced on the opposite page.

the evolution of human races must have been the alternating occurrence of periods of in-breeding (endogamy), tending to stability and sameness, and periods of out-breeding (exogamy), tending to changefulness and diversity.

Thus we may distinguish several more or less clearly defined primitive races of mankind—notably the African, the Australian, the Mongolian, and the Caucasian. The woolly-haired African race includes the negroes and the very primitive bushmen. The wavy- to curly-haired Australian race includes the Jungle Tribes of the Deccan, the Vedda of Ceylon, the Jungle Folk or Semang, and the natives of unsettled parts of Australia—all sometimes slumped together as "Pre-Dravidians." The straight-haired Mongols include those of Tibet, Indo-China, China, and Formosa, those of many oceanic islands, and of the north from Japan to Lapland. The Caucasians include Mediterraneans, Semites, Nordics, Afghans, Alpines, and many more.

There are very few corners of knowledge more difficult than that of the Races of Men, the chief reason being that there has been so much movement and migration in the course of the ages. One physical type has mingled with another, inducing strange amalgams and novelties. If we start with what might be called "zoological" races or strains differing, for instance, in their hair (woolly-haired Africans, straight-haired Mongols, curly- or wavy-haired Pre-Dravidians and Caucasians), we find these replaced by *peoples* who are mixtures of various races, "brethren by civilisation more than by blood." As Professor Flinders Petrie has said, the only meaning the term "race" now can have is that of a group of human beings whose type has been unified by their rate of assimilation exceeding the rate of change produced by the infiltration of foreign elements. It is probable, however, that the progress of precise anthropology will make it possible to distinguish the various racial "strains" that make up any people. For the human sense of race is so strong that it convinces us of reality even when scientific definition is impossible. It was this the British sailor expressed in his answer to the question "What is a Dago?" "Dagoes," he replied, "is anything wot isn't our sort of chaps."

Steps in Human Evolution.

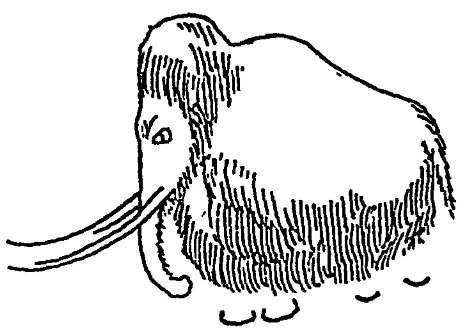
Real men arose, we believe, by variational uplifts of considerable magnitude which led to big and complex brains and to the power of reasoned discourse. In some other lines of mammalian evolution there were from time to time great advances in the size and complexity of the brain, as is clear, for instance, in the case of horses and elephants. The same is true of birds as compared with reptiles, and everyone recognises the high level of excellence that has been attained by their vocal powers. How these great cerebral advances came about we do not

know, but it has been one of the main trends of animal evolution to improve the nervous system. Two suggestions may be made. First, the prolongation of the period of ante-natal life, in intimate physiological partnership with the mother, may have made it practicable to start the higher mammal with a much better brain than in the lower orders, like Insectivores and Rodents, and still more Marsupials, where the period before birth (gestation) is short. Second, we know that the individual development of the brain is profoundly influenced by the internal secretions of certain ductless glands, notably the thyroid. When this organ is not functioning properly the child's brain development is arrested. It may be that increased production of certain hormones—itself, of course, to be accounted for—may have stimulated brain development in man's remote ancestors.

Given variability along the line of better brains and given a process of discriminate sifting which would consistently offer rewards to alertness and foresight, to kin-sympathy and parental care, there seems no great difficulty in imagining how Man would evolve. We must not think of an Aristotle or a Newton, except as fine results which justify all the groaning and travailing; we must think of average men, of primitive peoples to-day, and of our forbears long ago. We must remember how much of man's advance is dependent on the external registration of the social heritage, not on the slowly changing natural inheritance.

Looking backwards it is impossible, we think, to fail to recognise progress. There is a ring of truth in the fine description Æschylus gave of primitive men that—" first, beholding they beheld in vain, and, hearing, heard not, but, like shapes in dreams, mixed all things wildly down the tedious time, nor knew to build a house against the sun with wicketed sides, nor any woodwork knew, but lived like silly ants, beneath the ground, in hollow caves unsunned. There came to them no steadfast sign of winter, nor of spring flower-perfumed, nor of summer full of fruit, but blindly and lawlessly they did all things."

Contrast this picture with the position of man to-day. He has mastered the forces of Nature and is learning to use their resources more and more economically; he has harnessed electricity to his chariot and he has made the ether carry his messages. He tapped supplies of material which seemed for centuries unavailable, having learned, for instance, how to capture and utilise the free nitrogen of the air. With his telegraph and " wireless " he has annihilated distance, and he has added to his navigable kingdom the depths of the sea and the heights of the air. He has conquered one disease after another, and the young science of heredity is showing him how to control in his domesticated animals and cultivated plants the nature of the generations yet unborn. With all his faults he has his ethical face set in the right direction. The main line of movement is towards the fuller embodiment of the true, the beautiful, and the good in healthy lives which are increasingly a satisfaction in themselves.



A MAMMOTH DRAWN ON THE WALL OF THE FONT-DE-GAUME CAVERN.

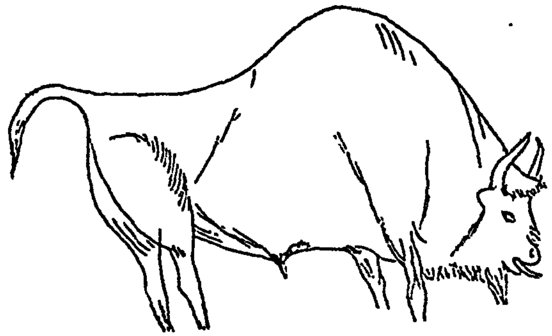
The mammoth age was in the Middle Pleistocene, while Neanderthal Men still flourished, probably far over 30,000 years ago.

Many, we believe, were the gains that rewarded the arboreal apprenticeship of man's ancestors. Many, likewise, were the results of leaving the trees and coming down to the solid earth—a transition which marked the emergence of more than tentative men. What great steps followed?

Factors in Human Progress.

Some of the greatest were—the working out of a spoken language and of external methods of registration; the invention of tools; the discovery of the use of fire; the utilisation of iron and other metals; the taming of wild animals such as dog and sheep, horses and cattle; the cultivation of wild plants such as wheat and rice; and the irrigation of fields. All through the ages necessity has been the mother of invention and curiosity its father; but perhaps we miss the heart of the matter if we forget the importance of some leisure time—wherein to observe and think. If our earth had been so clouded that the stars were hidden from

men's eyes the whole history of our race would have been different. For it was through his leisure-time observations of the stars that early man discovered the regularity of the year and got his fundamental impressions of the order of Nature—on which all his science is founded.



A GRAZING BISON, DELICATELY AND CAREFULLY DRAWN, ENGRAVED ON A WALL OF THE ALTAMIRA CAVE, NORTHERN SPAIN.

This was the work of a Reindeer Man or Cromagnard, in the Upper or Post-Glacial Pleistocene, perhaps 25,000 years ago. Firelight must have been used in making these cave drawings and engravings.

If we are to think clearly of the factors of human progress we must recall the three great biological ideas—the living organism, its environment, and its functioning. For man these mean (1) the living creature, the outcome of parents and ancestors, a fresh expression of a bodily and mental inheritance; (2) the surroundings, including climate and soil, the plants and animals these allow; and (3) the activities of all sorts, occupations and habits, all the actions and reactions between man and his milieu. In short, we have to deal with Folk, Place, Work; the *Famille, Lieu, Travail* of the LePlay school.

As to Folk, human progress depends on intrinsic racial qualities—notably health and vigour of body, clearness and alertness of mind, and an indispensable sociality. The most powerful factors in the world are clear ideas in the minds of energetic men of good will. The differences in bodily and mental health which mark races, and stocks within a people, just as they mark individuals, are themselves traceable back to germinal variations or mutations, and to the kind of sifting to which the race or stock has been subjected. Easygoing conditions are not only without stimulus to new departures, they are without the sifting which progress demands.

As to Place, it is plain that different areas differ greatly in their material resources and in the availability of these. Moreover, even when abundant material resources are present, they will not make for much progress unless the climate is such that they can be readily utilised. Indeed, climate has been one of the great factors in civilisation, here stimulating and there depressing energy, in one place favouring certain plants and animals important to man, in another place preventing their presence. Moreover, climate has slowly changed from age to age.

As to Work, the form of a civilisation is in some measure dependent on the primary occupations, whether hunting or fishing, farming or shepherding; and on the industries of later ages which have a profound moulding effect on the individual at least. We cannot, however, say more than that the factors of human progress have always had these three aspects, Folk, Place, Work, and that if progress is to continue on stable lines it must always recognise the essential correlation of fitter folk in body and mind; improved habits and functions, alike in work and leisure; and bettered surroundings in the widest and deepest sense.

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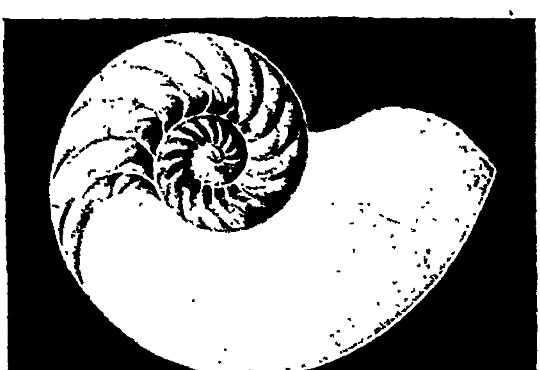
VI
EVOLUTION GOING ON

EVOLUTION, as we have seen in a previous chapter, is another word for race-history. It means the ceaseless process of Becoming, linking generation to generation of living creatures. The Doctrine of Evolution states the fact that the present is the child of the past and the parent of the future. It comes to this, that the living plants and animals we know are descended from ancestors on the whole simpler, and these from others likewise simpler, and so on, back and back—till we reach the first living creatures, of which, unfortunately, we know nothing. Evolution is a process of racial change in a definite direction, whereby new forms arise, take root, and flourish, alongside of or in the place of their ancestors, which were in most cases rather simpler in structure and behaviour.

The rock-record, which cannot be wrong, though we may read it wrongly, shows clearly that there was once a time in the history of the Earth when the only backboned animals were Fishes. Ages passed, and there evolved Amphibians, with fingers and toes, scrambling on to dry land. Ages passed, and there evolved Reptiles, in bewildering profusion. There were fish-lizards and sea-serpents, terrestrial dragons and flying dragons, a prolific and varied stock. From the terrestrial Dinosaurs it seems that Birds and Mammals arose. In succeeding ages there evolved all the variety of Birds and all the variety of Mammals. Until at last arose the Man. The question is whether similar processes of evolution are still going on.

We are so keenly aware of rapid changes in mankind, though these concern the social heritage much more than the flesh-and-blood natural inheritance, that we find no difficulty in the idea that evolution is going on in mankind. We know the contrast between modern man and primitive man, and we are convinced that in the past, at least, progress has been a reality. That degeneration may set in is an awful possibility — involution rather than evolution—but even if going back became for a time the rule, we cannot give up the hope that the race would recover itself and begin afresh to go forward. For although there have been retrogressions in the history of life, continued through unthinkably long ages, and although great races, the Flying Dragons for instance, have become utterly extinct, leaving no successors whatsoever, we feel sure that there has been on the whole a progress towards nobler, more masterful, more emancipated, more intelligent, and *better* forms of life—a progress



PHOTOGRAPH OF A MEDIAN SECTION THROUGH THE SHELL OF THE PEARLY NAUTILUS.

It is only the large terminal chamber that is occupied by the animal.

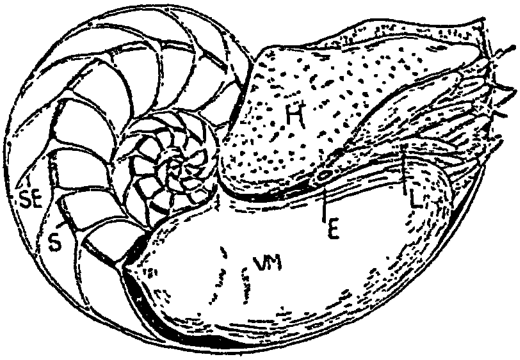
PHOTOGRAPH OF THE ENTIRE SHELL OF THE PEARLY NAUTILUS.

The headquarters of the Nautilus are in the Indian and Pacific Oceans. They sometimes swim at the surface of the sea, but they usually creep slowly about on the floor of comparatively shallow water.

towards what mankind at its best has always regarded as best, i.e. affording most enduring satisfaction. So we think of evolution going on in mankind, evolution chequered by involution, but on the whole *progressive evolution.*

Evolutionary Prospect for Man.

It is not likely that man's body will admit of *great* change, but there is room for some improvement, e.g. in the superfluous length of the food-canal and the overcrowding of the teeth. It is likely, however, that there will be constitutional changes, e.g. of prolonged youthfulness,



NAUTILUS.

A section through the Pearly Nautilus, *Nautilus pompilius,* common from Malay to Fiji. The shell is often about 9 inches long. The animal lives in the last chamber only, but a tube (S) runs through the empty chambers, perforating the partitions (SE). The bulk of the animal is marked VM; the eye is shown at E; a hood is marked H; round the mouth there are numerous lobes (L) bearing protrusible tentacles, some of which are shown. When the animal is swimming near the surface the tentacles radiate out in all directions, and it has been described as "a shell with something like a cauliflower sticking out of it." The Pearly Nautilus is a good example of a conservative type, for it began in the Triassic Era. But the family of Nautiloids to which it belongs illustrates very vividly what is meant by a dwindling race. The Nautiloids began in the Cambrian, reached their golden age in the Silurian, and began to decline markedly in the Carboniferous. There are 2,500 extinct or fossil species of Nautiloids, and only 4 living to-day.

a higher standard of healthfulness, and a greater resistance to disease. It is justifiable to look forward to great improvements in intelligence and in control. The potentialities of the human brain, as it is, are far from being utilised to the full, and new departures of promise are of continual occurrence. What is of great importance is that the new departures or variations which emerge in fine children should be fostered, not nipped in the bud, by the social environment, education included. The evolutionary prospect for man is promising.

But it is very important to realise that among plants and animals likewise, *Evolution is going on.*

The Fountain of Change: Variability.

On an ordinary big clock we do not readily see that even the minute hand is moving, and if the clock struck only once in a hundred years we can conceive of people arguing whether the hands did really move at all. So it often is with the changes that go on from generation to generation in living creatures. The flux is so slow, like the flowing of a glacier, that some people fail to be convinced of its reality. And it must, of course, be admitted that some kinds of living creatures, like the Lamp-shell *Ligula* or the Pearly Nautilus, hardly change from age to age, whereas others, like some of the birds and butterflies, are always giving rise to something new. The Evening Primrose among plants, and the Fruit-fly, Drosophila, among animals, are well-known examples of organisms which are at present in a sporting or mutating mood.

Certain dark varieties of moth, e.g. of the Peppered Moth, are taking the place of the paler type in some parts of England, and the same is true of some dark forms of Sugar-bird in the West Indian islands. Very important is the piece of statistics worked out by Professor R. C. Punnett, that "if a population contains ·001 per cent of a new variety, and if that variety has even a 5 per cent selection advantage over the original form, the latter will almost completely disappear in less than a hundred generations." This sort of thing has been going on all over the world for untold ages, and the face of animate nature has consequently changed.

We are impressed by striking novelties that crop up—a clever dwarf, a musical genius, a calculating boy, a cock with a 10 ft. tail, a "wonder-horse" with a mane reaching to the ground, a tailless cat, a white blackbird, a copper beech, a Greater Celandine with much cut up leaves; but this sort of mutation is common, and smaller, less brusque variations are commoner still. *They form the raw materials of possible evolution.* We are actually standing before an apparently inexhaustible fountain of change. This is evolution going on.

The Sporting Jellyfish.

It is of interest to consider a common animal like the jellyfish Aurelia. It is admirably suited for a leisurely life in the open sea, where it swims about by contracting its saucer-shaped body, thus

driving water out from its concavity. By means of millions of stinging cells on its four frilled lips and on its marginal tentacles it is able to paralyse and lasso minute crustaceans and the like, which it then wafts into its mouth. It has a very eventful life-history, for it has in its early youth to pass through a fixed stage, fastened to rock or seaweed, but it is a successful animal, well suited for its habitat, and practically cosmopolitan in its distribution. It is certainly an old-established creature. Yet it is very variable in colour and in size, and even in internal structure. Very often it is the size of a saucer or a soup-plate, but giants over two feet in diameter are well known. Much more important, however, than variations in colour and size are the inborn changes in structure. Normally a jellyfish has its parts in fours or multiples of four. Thus it has four frilled lips, four tufts of digestive filaments in its stomach, and four brightly coloured reproductive organs. It has eight sense-organs round the margin of its disc, eight branched and eight unbranched radial canals running from the central stomach to a canal round the circumference. The point of giving these details is just this, that every now and then we find a jellyfish with its parts in sixes, fives, or threes, and with a multitude of minor idiosyncrasies. *Even in the well-established jellyfish there is a fountain of change.*

Photo: W. S. Berridge.

SHOEBILL.

A bird of a savage nature, never mixing with other marsh birds. According to Dr. Chalmers Mitchell, it shows affinities to herons, storks, pelicans, and gannets, and is a representative of a type equal to both herons and storks and falling between the two.

§ 1

Evolution of Plants.

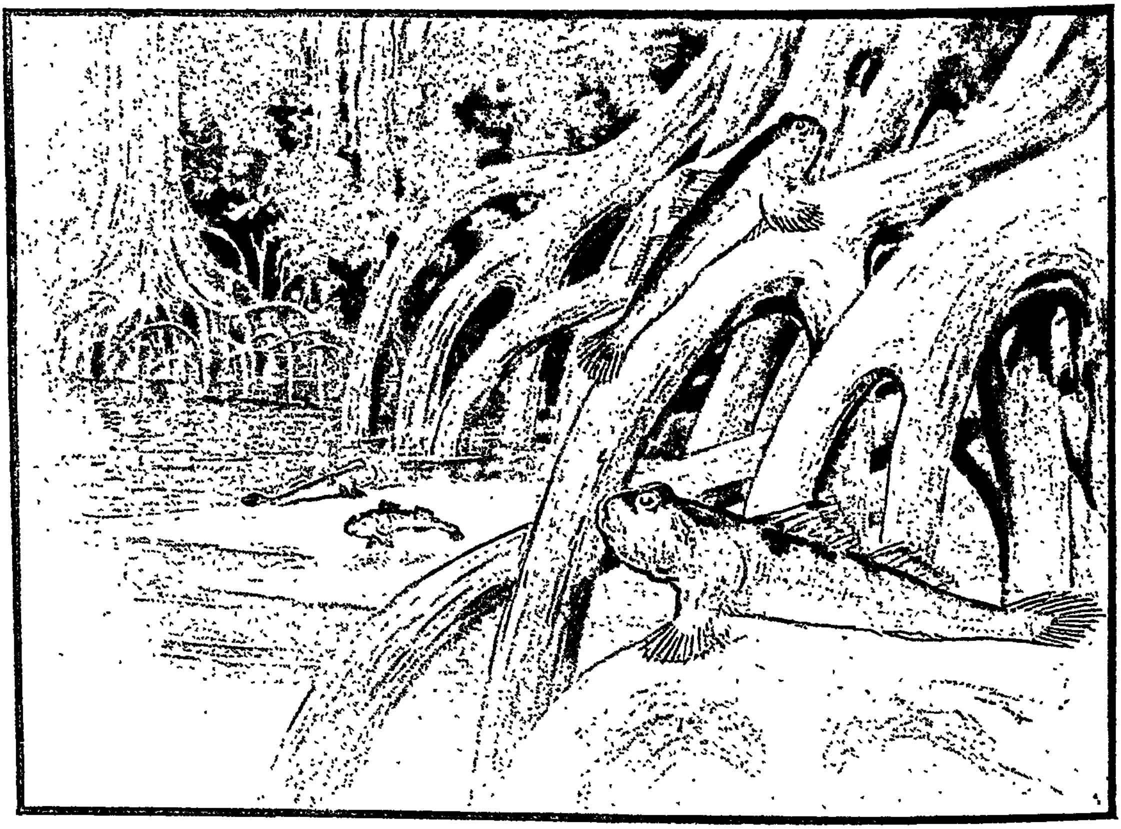
It is instructive to look at the various kinds of cabbages, such as cauliflower and Brussels sprouts, kale and curly greens, and remember that they are all scions of the not very promising wild cabbage found on our shores. And are not all the aristocrat apple-trees of our orchards descended from the plebeian crab-apple of the roadside? We know far too little about the precise origin of our cultivated plants, but there is no doubt that after man got a hold of them he took advantage of their variability to establish race after race, say, of rose and chrysanthemum, of potato and cereal. The evolution of cultivated plants is continuing before our eyes, and the creations of Mr. Luther Burbank, such as the stoneless plum and the primus berry, the spineless cactus and the Shasta daisy, are merely

striking instances of what is always going on.

There is reason to believe that the domestic dog has arisen three times, from three distinct ancestors—a wolf, a jackal, and a coyote. So a multiple pedigree must be allowed for in the case of the dog, and the same is true in regard to some other domesticated animals. But the big fact is the great variety of breeds that man has been able to fix, after he once got started with a domesticated type. There are over 200 well-marked breeds of domestic pigeons, and there is very strong evidence that all are descended from the wild rock-dove, just as the numerous kinds of poultry are descended from the jungle-fowl of some parts of India and the Malay Islands. Even more familiar is the way in which man has, so to speak, unpacked the complex fur of the wild rabbit, and established all the numerous colour-varieties which we see among domestic rabbits. And apart from colour-varieties there are long-haired Angoras and quaint lop-eared forms, and many more besides. All this points to evolution going on.

The Romance of the Wheat.

It is well-known that Neolithic man grew wheat, and some authorities have put the date of the first wheat harvest at between fifteen thousand and ten thousand years ago. The ancient civilisations of Babylonia, Egypt, Crete, Greece, and Rome were largely based on wheat, and it is highly probable that the first great wheatfields were in the fertile land between the Tigris and the Euphrates. The oldest Egyptian tombs that contain wheat, which, by the way, never germinates after its millennia of rest, belong to the First Dynasty, and are about six thousand years old. But there must have been a long history of wheat before that.



THE WALKING-FISH OR MUD-SKIPPER (PERIOPHTHALMUS), COMMON AT THE MOUTHS OF RIVERS IN TROPICAL AFRICA, ASIA, AND NORTH-WEST AUSTRALIA.

It skips about by means of its strong pectoral fins on the mud-flats; it jumps from stone to stone, hunting small shore-animals; it climbs up the roots of the mangrove-trees. The close-set eyes protrude greatly and are very mobile. The tail seems to help in respiration.

PAINTINGS ON THE ROOF OF THE ALTAMIRA CAVE IN NORTHERN SPAIN, SHOWING A BISON ABOVE AND A GALLOPING BOAR BELOW

The artistic drawings, over 2 feet in length, were made by the Reindeer Men or " Cromagnards " in the time of the Upper or Post-Glacial Pleistocene, before the appearance of the Neolithic men.

Now it is a very interesting fact that the almost certain ancestor of the cultivated wheat is at present living on the arid and rocky slopes of Mount Hermon. It is called *Triticum hermonis*, and it is varying notably to-day, as it did long ago when it gave rise to the emmer, which was cultivated in the Neolithic Age and is the ancestor of all our ordinary wheats. We must think of Neolithic man noticing the big seeds of this Hermon grass, gathering some of the heads, breaking the brittle spikelet-bearing axis in his fingers, knocking off the rough awns or bruising the spikelets in his hand till the glumes or chaff separated off and could be blown away, chewing a mouthful of the seeds—and resolving to sow and sow again.

Photo: "The Times."

THE AUSTRALIAN MORE-PORK OR PODARGUS.

A bird with a frog-like mouth, allied to the British Nightjar. Now in the London Zoological Gardens.

The capacious mouth is well suited for engulfing large insects such as locusts and mantises, which are mostly caught on the trees. During the day the More-pork or Frog-mouth sleeps upright on a branch, and its mottled brown plumage makes it almost invisible.

That was the beginning of a long story, in the course of which man took advantage of the numerous variations that cropped up in this sporting stock and established one successful race after another on his fields. Virgil refers in the "Georgics" to the gathering of the largest and fullest ears of wheat in order to get good seed for another sowing, but it was not till the first quarter of the nineteenth century that the great step was taken, by men like Patrick Sheriff of Haddington, of deliberately selecting individual ears of great excellence and segregating their progeny from mingling with mediocre stock. This is the method which has been followed with remarkable success in modern times.

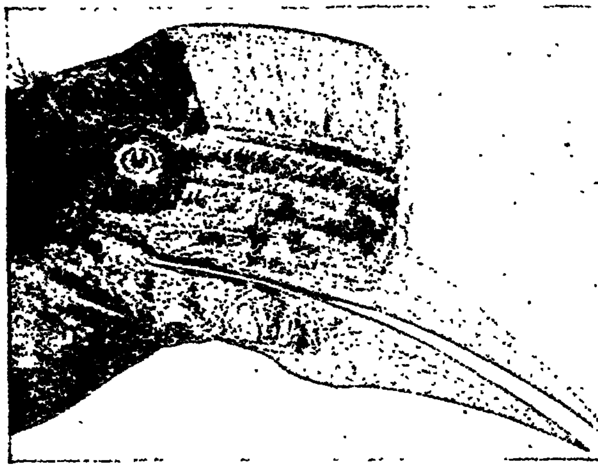
One of the factors that assisted the Allies in overcoming the food crisis in the darkest period of the war was the virtue of Marquis Wheat, a very prolific, early ripening, hard, red spring wheat with excellent milling and baking qualities. It is now the dominant spring wheat in Canada and the United States, and it has enormously increased the real wealth of the world in the last ten years (1921). Now our point is simply that this Marquis Wheat is a fine example of evolution going on. In 1917 upwards of 250,000,000 bushels of this wheat were raised in North America, and in 1918 upwards of 300,000,000 bushels; yet the whole originated from a single grain planted in an experimental plot at Ottawa by Dr. Charles E. Saunders so recently as the spring of 1903.

We must not dwell too long on this particular instance of evolution, though it has meant much to our race. We wish, however, following Professor Buller's *Essays on Wheat* (1919), to explain the method by which this good seed was discovered. From one we may learn all. The parent of Marquis Wheat on the male side was the mid-European Red Fife—a first-class cereal. The parent on the female side was less promising, a rather nondescript, not pure-bred wheat, called Red Calcutta, which was imported from India into Canada about thirty years ago. The father was part of a cargo that came from the Baltic to Glasgow, and was happily included

the moles are spoiling the pasture. "But while the parts fluctuate, the fauna as a whole follows a path of its own. As well as internal tides which swing to and fro about an average level, there is a drift which carries the fauna bodily along an 'irretraceable course.'" This is partly due to considerable changes of climate, for climate calls the tune to which living creatures dance, but it is also due to new departures among the animals themselves. We need not go back to the extinct animals and lost faunas of past ages—for Britain has plenty relics of these—which "illustrate the reality of the faunal drift," but it may be very useful, in illustration of evolution in being, to notice what has happened in Scotland since the end of the Great Ice Age.

Some nine thousand years ago or more, certain long-headed, square-jawed, short-limbed, but agile hunters and fishermen, whom we call Neolithic Man, established themselves in Scotland. What was the state of the country then? "It was a country of swamps, low forests of birch, alder, and willow, fertile meadows and snow-capped mountains. Its estuaries penetrated further inland than they now do, and the sea stood at the level of the Fifty-Foot Beach. On its plains and in its forests roamed many creatures which are strange to the fauna of to-day—the Elk and the Reindeer, Wild Cattle, the Wild Boar and perhaps Wild Horses, a fauna of large animals which paid toll to the European Lynx, the Brown Bear and the Wolf. In all likelihood, the marshes resounded to the boom of the Bittern and the plains to the breeding calls of the Crane and the Great Bustard." Such is Dr. Ritchie's initial picture.

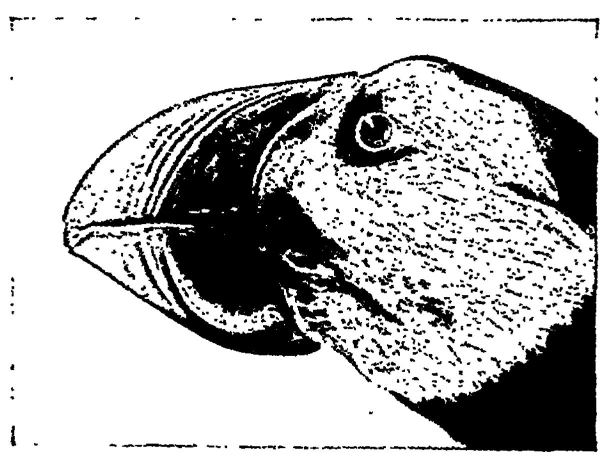
Now what happened in this kingdom of Caledonia which Neolithic Man had found? He began to introduce domesticated animals, and that meant a thinning of the ranks of predaceous creatures. "Safety first" was the dangerous motto in obedience to which man exterminated the lynx, the brown bear, and the wolf. Other creatures, such as the great auk, were destroyed for food, and others like the marten for their furs. Small



HORNBILL'S BILL, ADAPTED FOR EXCAVATING A NEST IN A TREE, AND ALSO FOR SEIZING AND BREAKING DIVERSE FORMS OF FOOD, FROM MAMMALS TO TORTOISES, FROM ROOTS TO FRUITS.

The use of the helmet or casque is obscure.

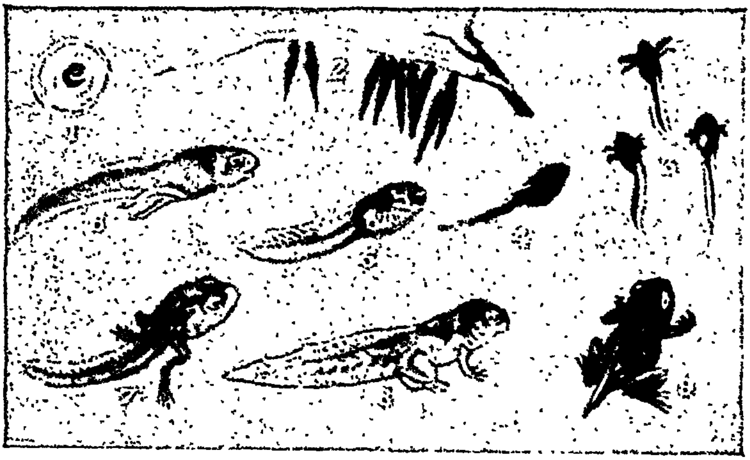
FALCON'S BILL, ADAPTED FOR SEIZING, KILLING, AND TEARING SMALL MAMMALS AND BIRDS.



PUFFIN'S BILL, ADAPTED FOR CATCHING SMALL FISHES NEAR THE SURFACE OF THE SEA, AND FOR HOLDING THEM WHEN CAUGHT AND CARRYING THEM TO THE NEST.

The scaly covering is moulted in the autumn.

pests were destroyed to protect the beginnings of agriculture; larger animals like the boar were hunted out of existence; others, like the pearl-bearing river-mussels, yielded to subtler demands. No doubt there was protection also —protection for sport, for utility, for æsthetic reasons, and because of humane sentiments; even wholesome superstitions have safeguarded the robin redbreast and the wren. There were introductions too—the rabbit for utility, the pheasant for sport, and the peacock for amenity. And every introduction, every protection, every killing out had its far-reaching influences.



LIFE-HISTORY OF A FROG.

1, Before hatching; 2, newly hatched larvæ hanging on to water-weed; 3, with external gills; 4, external gills are covered over and are absorbed; 5, limbless larva about a month old with internal gills; 6, tadpole with hind-legs, about two months old; 7, with the fore-limbs emerging; 8, with all four legs free; 9, a young frog, about three months old, showing the almost complete absorption of the tail and the change of the tadpole mouth into a frog mouth.

But if we are to picture the evolution going on, we must think also of man's indirect interference with animal life. He destroyed the forests, he cultivated the wild, he made bridges, he allowed aliens, like rats and cockroaches, to get in unawares. Of course, he often did good, as when he drained swamps and got rid of the mosquitoes which once made malaria rife in Scotland.

What has been the net result? Not, as one might think for a moment, a reduction in the *number* of different kinds of animals. Fourteen or so species of birds and beasts have been banished from Scotland since man interfered, but as far as numbers go they have been more than replaced by deliberate introductions like fallow deer, rabbit, squirrels, and pheasant, and by accidental introductions like rats and cockroaches. But the change is rather in *quality* than in quantity; the smaller have taken the place of the larger, rather paltry pigmies of noble giants. Thus we get a vivid idea that evolution, especially when man interferes, is not necessarily progressive. That depends on the nature of the sieves with which the living materials are sifted. As Dr. Ritchie well says, the standard of the wild fauna as regards size has fallen and is falling, and it is not in size only that there is loss, there is a deterioration of quality. "For how can the increase of Rabbits and Sparrows and Earthworms and Caterpillars, and the addition of millions of Rats and Cockroaches and Crickets and Bugs, ever take the place of those fine creatures round the memories of which the glamour of Scotland's past still plays—the Reindeer and the Elk, the Wolf, the Brown Bear, the Lynx, and the Beaver, the Bustard, the Crane, the Bumbling Bittern, and many another, lost or disappearing." Thus we see again that evolution is going on.

§ 3

The Adventurers.

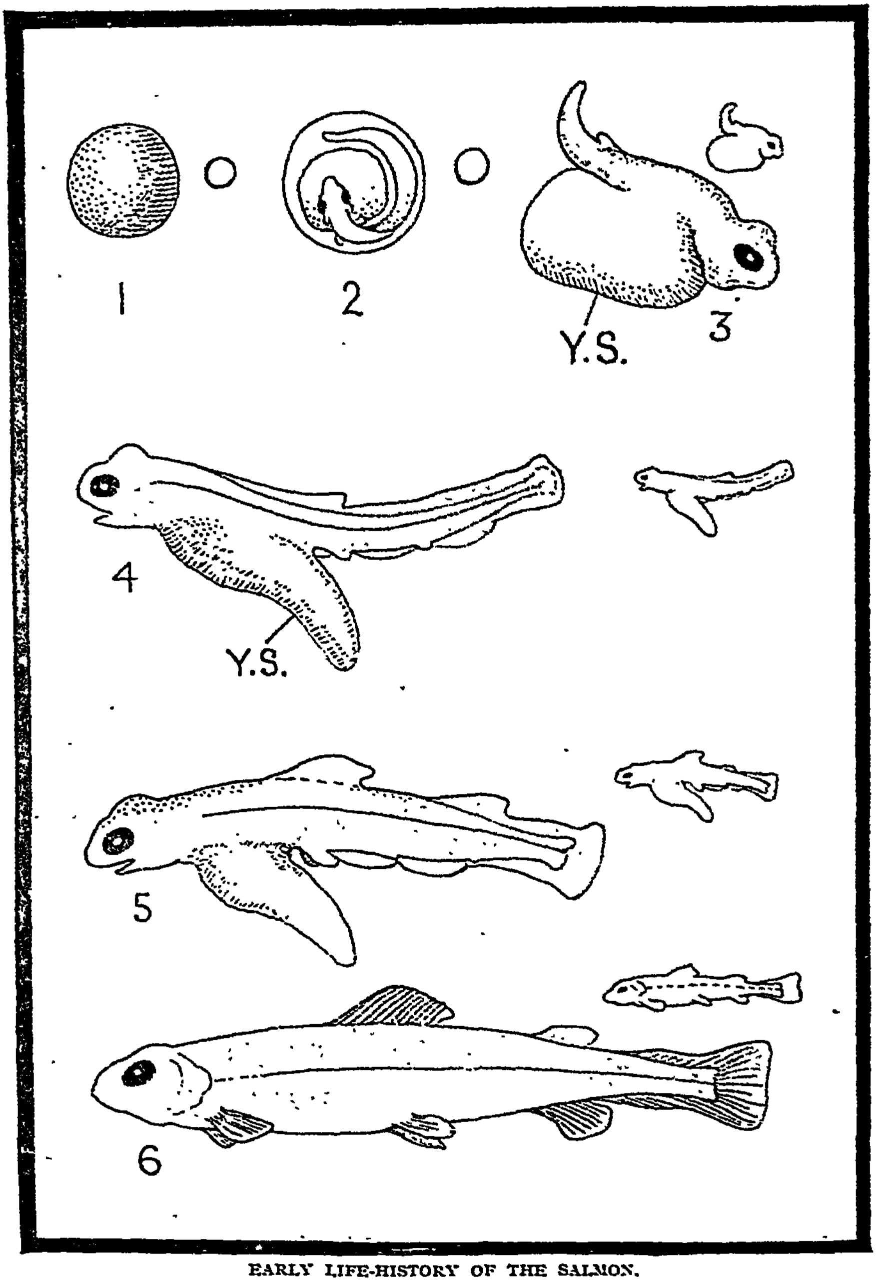
All through the millions of years during which animals have tenanted the earth and the waters under the earth, there has been a search for new kingdoms to conquer, for new corners in which to make a home. And this still goes on. *It has been and is one of the methods of evolution to fill every niche of opportunity.* There is a spider that lives inside a pitcher-plant, catching some of the inquisitive insects which slip down the treacherous internal surface of the trap. There is another that makes its home in crevices among the rocks on the shore of the Mediterranean, or even in empty tubular shells, keeping the water out, more or less successfully, by spinning

threads of silk across the entrance to its retreat. The beautiful brine-shrimp, *Artemia salina*, that used to occur in British salterns has found a home in the dense waters of the Great Salt Lake of Utah. Several kinds of earthworms have been found up trees, and there is a fish, Arges, that climbs on the stones of steep mountain torrents of the Andes. The intrepid explorers of the *Scotia* voyage found quite a number of Arctic terns spending our winter within the summer of the Antarctic Circle—which means girdling the globe from pole to pole; and every now and then there are incursions of rare birds, like Pallas's Sand-grouse, into Britain, just as if they were prospecting in search of a promised land. Twice or thrice the distinctively North American Killdeer Plover has been found in Britain, having somehow or other got across the Atlantic. We miss part of the meaning of evolution if we do not catch this note of insurgence and adventure, which some animal or other never ceases to sound, though many establish themselves in a security not easily disturbed, and though a small minority give up the struggle against the stream and are content to acquiesce, as parasites or rottenness eaters, in a drifting life of ease.

THE BIG ROBBER-CRAB (*BIRGUS LATRO*), THAT CLIMBS THE COCO-NUT PALM AND BREAKS OFF THE NUTS.

It occurs on islands in the Indian Ocean and Pacific, and is often found far above sea-level. It is able to breathe dry air. One is seen emerging from its burrow, which is often lined with coco-nut fibre. The empty coco-nut shell is sometimes used by the Robber-Crab for the protection of its tail.

More important than very peculiar cases is the broad fact that over and over again in different groups of animals there have been attempts to master different kinds of haunts—such as the underground world, the trees, the freshwaters, and the air. There are burrowing amphibians, burrowing reptiles, burrowing birds, and burrowing mammals; there are tree-toads, tree-snakes, tree-lizards, tree-kangaroos, tree-sloths, tree-shrews, tree-mice, tree-porcu-



EARLY LIFE-HISTORY OF THE SALMON.

1. The fertilised egg, shed in the gravelly bed of the river.

2. The embryo within the egg, just before hatching. The embryo has been constricted off from the yolk-laden portion of the egg.

3. The newly hatched salmon, or alevin, encumbered with its legacy of yolk (Y.S.).

4 and 5. The larval salmon, still being nourished from the yolk-sac (Y.S.), which is diminishing in size as the fish grows larger.

6. The salmon fry about six weeks old, with the yolk fully absorbed, so that the young fish has now to feed for itself. The fry become parr, which go to the sea as smolts, and return as grilse.

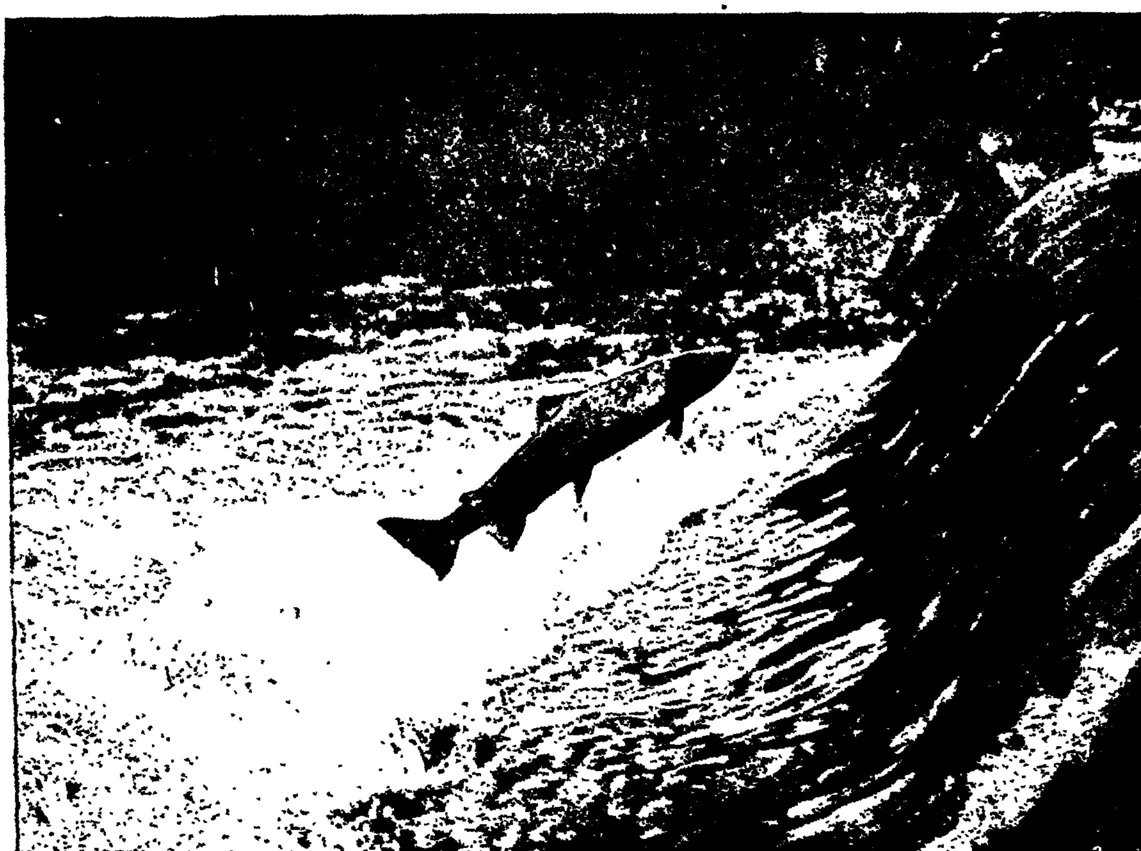
In all cases the small figures to the right indicate the natural size.

pines, and so on; enough of a list to show, without mentioning birds, how many different kinds of animals have entered upon an arboreal apprenticeship—an apprenticeship often with far-reaching consequences. What the freeing of the hand from being an organ of terrestrial support has meant in the evolution of monkeys is a question that gives a spur to our imagination.

The Case of the Robber-Crab.

On some of the coral islands of the Indian and Pacific Oceans there lives a land-crab, Birgus, which has learned to breathe on land. It breathes dry air by means of curious blood-containing tufts in the upper part of its gill-cavity, and it has also rudimentary gills. It is often about a foot long, and it has very heavy great claws, especially on the left-hand side. With this great claw it hammers on the "eye-hole" of a coco-nut, from which it has torn off the fibrous husk. It hammers until a hole is made by which it can get at the pulp. Part of the shell is sometimes used as a protection for the soft abdomen—for the robber-crab, as it is called, is an offshoot from the hermit-crab stock. Every year this quaint explorer, which may go far up the hills and climb the coco-palms, has to go back to the sea to spawn. The young ones are hatched in the same state as in our common shore-crab. That is to say, they are free-swimming larvæ which pass through an open-water period before they settle down on the shore, and eventually creep up on to dry land. Just as open-water turtles lay their eggs on sandy shores, going back to their old terrestrial haunt, so the robber-crab, which has almost conquered the dry land, has to return to the sea-shore to breed. There is a peculiar interest in the association of the robber-crab with the coco-palm, for that tree is not a native of these coral islands, but has been introduced, perhaps from Mexico, by the Polynesian mariners before the discovery of America by Columbus. So the learning to deal with coco-nuts is a recent achievement, and we are face to face with a very good example of evolution going on.

In late autumn or in winter the salmon spawn in the rivers. The female makes a shallow trough in the gravel by moving her tail from



THE SALMON LEAPING AT THE FALL IS A MOST FASCINATING SPECTACLE.

Again and again we see them jumping out of the seething foam beneath the fall, casting themselves into the curtain of the down-rushing water, only to be carried back by it into the depths whence they have risen. One here and another there makes its effort good, touches the upper lip of the cataract, gives a swift stroke of its tail, and rushes on towards those upper reaches which are the immemorial spawning beds of its race.

side to side, and therein lays many eggs. The male, who is in attendance, fertilises these with the milt, and then the female covers them deeply with gravel. The process is repeated over and over again for a week or more till all the eggs are shed. For three to four months the eggs develop, and eventually there emerge the larvæ or *alevins*, which lurk among the pebbles. They cannot swim much, for they are encumbered by a big legacy of yolk. In a few weeks, perhaps eight, the protruding bag of yolk has disappeared and the *fry*, about an inch long, begin to move about more actively and to fend for themselves. By the end of the year they have grown to be rather trout-like *parr*, about four inches long. In two years these are double that length. Usually in the second year, but it may be earlier or later, the parr become silvery *smolts*, which go out to sea, usually about the month of May. They feed on young herring and the like and grow large and strong. When they are about three and a half years old they come up the rivers as *grilse* and may spawn. Or they may pass through the whole grilse stage in the sea and come up the rivers with all the characters of the full-grown fish. In many cases the salmon spawn only once, and some (they are called *kelts* after spawning) are so much exhausted by starting a new generation that they die or fall a victim to otters and other enemies. In the case of the salmon of the North Pacific (in the genus *Oncorhynchus*, not *Salmo*) all the individuals die after spawning, none being able to return to the sea. It must be remembered that full-grown salmon do not as a rule feed in fresh water, though they may be unable to resist snapping at the angler's strange creations. A very interesting fact is that the salmon keeps as it were a diary of its movements, which vary a good deal in different rivers. This diary is written in the scales, and a careful reading of the concentric lines on the scales shows the age of the fish, and when it went out to sea, and whether it has spawned or not, and more besides.

The Story of the Salmon.

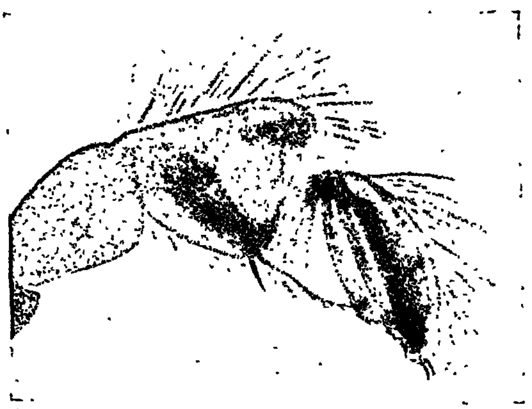


Photo: J. J. Ward, F.E.S.

HIND-LEG OF WHIRLIGIG BEETLE WHICH HAS BECOME BEAUTIFULLY MODIFIED FOR AQUATIC LOCOMOTION.

The flattened tips form an expanding "fan" or paddle, which opens and closes with astonishing rapidity. The closing of the "fan," like the "feathering" of an oar, reduces friction when the leg is being moved forwards for the next stroke.

Interpretation of the Salmon's Story.

When an animal frequents two different haunts, in one of which it breeds, it is very often safe to say that the breeding-place represents the original home. The flounder is quite comfortable far up the rivers, but it has to go to the shore-waters to spawn, and there is no doubt that the flounder is a marine fish which has recently learned to colonise the freshwaters. Its relatives, like plaice and sole, are strictly marine. But it is impossible to make a dogma of the rule that the breeding-place corresponds to the original home. Thus some kinds of bass, which belong to the marine family of sea-perches, live in the sea or in estuaries, while two have become permanent residents in fresh water. Or, again, the members of the herring family are very distinctively marine, but the shad, which belong to this family, spawn in rivers and may spend their lives there.

So there are two different ways of interpreting the life-history of the salmon. Some authorities regard the salmon as a marine fish which is establishing itself in fresh water. But others read the story the other way and regard the salmon as a member of a freshwater race, that has taken to the sea for feeding purposes. In regard to trout, we know that the ranks of those in rivers and lakes are continually being reinforced by migrants from the sea, and that some trout go down to the sea while others remain in the freshwater. We know also in regard to a related fish, the char, that while the great majority of kinds are now permanent residents in cold and deep, isolated northern lakes, there are Arctic forms which live in the sea but enter the rivers to spawn. These facts

DIAGRAM OF THE LIFE-HISTORY OF THE COMMON EEL (*ANGUILLA VULGARIS*).

1. The transparent open-sea knife-blade-like larva called a Leptocephalus.
2 and 3. The gradual change of shape from knife-blade-like to cylindrical. The body becomes shorter and loses weight.
4. The young elver, at least a year old, which makes its way from the open sea to the estuaries and rivers. It is 2–3 inches long and almost cylindrical.
5. The fully-formed eel.

favour the view that the salmon was originally a marine fish. But there are arguments on both sides, and, for our present purpose, the important fact is that the salmon is conquering *two* haunts. Its evolution is going on.

The Romance of the Eel. Early in summer, at dates varying with the distance of the rivers from the open Atlantic, crowds of young eels or elvers come up-stream. Sometimes the procession or eel-fare includes thousands of individuals, each about the length of our first finger, and as thick as a stout knitting needle. They obey an inborn impulse to swim against the stream, seeking automatically to have both sides of their body equally stimulated by the current. So they go straight ahead. The obligation works only during the day, for when the sun goes down behind the hills the elvers snuggle under stones or beneath the bank and rest till dawn. In the course of time they reach

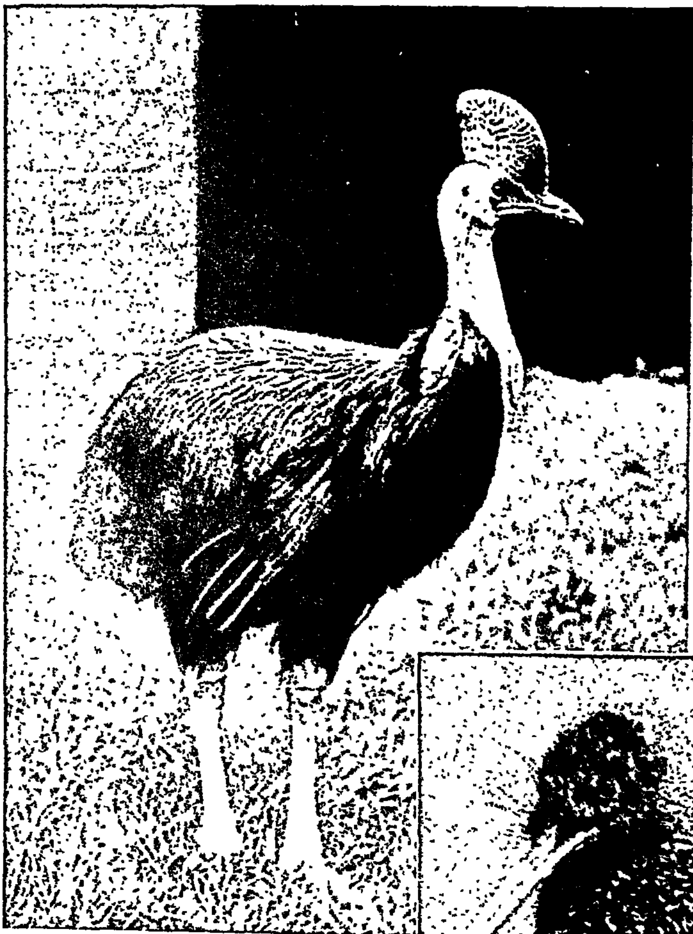


Photo: Gambier Bolton.

CASSOWARY.

Its bare head is capped with a helmet. Unlike the plumage of most birds its feathers are loose and hair-like, whilst its wings are merely represented by a few black quills. It is flightless and entirely dependent on its short powerful legs to carry it out of danger.

the quiet upper reaches of the river or go up rivulets and drain-pipes to the isolated ponds. Their impulse to go on must be very imperious, for they may wriggle up the wet moss by the side of a waterfall or even make a short excursion in a damp meadow.

In the quiet-flowing stretches of the river or in the ponds they feed and grow for years and years. They account for a good many young fishes. Eventually, after five or six years in the case of the males, six to eight years in the case of the females, the well-grown fishes, perhaps a foot and a half to two feet long, are seized by a novel restlessness. They are beginning to be mature. They put on a silvery jacket and become large of eye, and they return to the sea. In getting away from the pond it may be necessary to wriggle through the damp meadow-grass before reaching the river. They travel by night and rather excitedly. The Arctic Ocean is too cold for them and the North Sea too shallow. They must go far out to sea, to where the old margin of the once larger continent of Europe slopes down

Photo: Gambier Bolton.

THE KIWI, ANOTHER FLIGHTLESS BIRD, OF REMARKABLE APPEARANCE, HABITS, AND STRUCTURE.

to the great abysses, from the Hebrides southwards. Eels seem to spawn in the deep dark water; but the just liberated eggs have not yet been found. The young fry rises to near the surface and becomes a knife-blade-like larva, transparent all but its eye. It lives for many months in this state, growing to be about three inches long, rising and sinking in the water, and swimming gently. These open-sea young eels are known as Leptocephali, a name given to them before their real nature was proved. They gradually become shorter, and the shape changes from knife-blade-like to cylindrical. During this change they fast, and the weight of their delicate body decreases. They turn into glass-eels, about 2½ inches long, like a knitting-needle in girth. They begin to move towards the distant shores and rivers, and they may be a year and a half old before they reach their destination and go up-stream as elvers. Those that ascend the rivers of the Eastern Baltic must have journeyed three thousand miles. It is certain that no eel ever matures or spawns in fresh water. It is practically certain that all the young eels ascending the rivers of North Europe have come in from the Atlantic, some of them perhaps from the Azores or further out still. It is interesting to inquire how the young eels circumvent the Falls of the Rhine and get

THE AUSTRALIAN FRILLED LIZARD, WHICH IS AT PRESENT TRYING TO BECOME A BIPED.

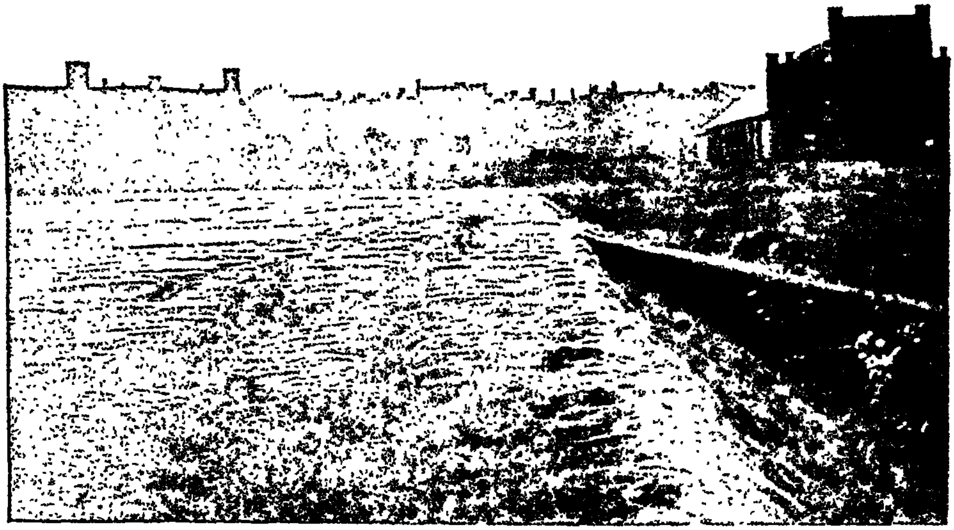
When it gets up on its hind-legs and runs for a short distance it folds its big collar round its neck.

into Lake Constance, or how their kindred on the other side of the Atlantic overcome the obstacle of Niagara; but it is more important to lay emphasis on the variety of habitats which this fish is trying — the deep waters, the open sea, the shore, the river, the pond, and even, it may be, a little taste of solid earth. It seems highly probable that the common eel is a deep-water marine fish which has learned to colonise the freshwaters. It has been adventurous and it has succeeded. The only shadow on the story of achievement is that there seems to be no return from the spawning. There is little doubt that death is the nemesis of their reproduction. In any case, no adult eel ever comes back from the deep sea. We are minded of Goethe's hard saying: "Death is Nature's expert advice to get plenty of life."

§ 4

Forming New Habits.

There is a well-known mudfish of Australia, Neoceratodus by name, which has turned its swim-bladder into a lung and comes to the surface to spout. It expels vitiated air with considerable force and takes fresh gulps. At the same time, like an ordinary fish, it has gills which allow the usual interchange of gases between the blood and the water. Now this Australian mudfish or double-breather (Dipnoan), which may be a



A CARPET OF GOSSAMER.

The silken threads used by thousands of gossamer spiders in their migrations are here seen entangled in the grass, forming what is called a shower of gossamer. At the edge of the grass the gossamer forms a curtain, floating out and looking extraordinarily like waves breaking on a sea-shore.

long way over a yard in length, is a direct and little-changed descendant of an ancient extinct fish, Ceratodus, which lived in Mesozoic times, as far back as the Jurassic, which probably means over five millions of years ago. The Queensland mudfish is an antiquity, and there has not been much change in its lineage for millions of years. We might take it as an illustration of the inertia of evolution. And yet, though its structure has changed but little, the fish probably illustrates evolution in process, for it is a fish that is learning to breathe dry air. It cannot leave the water; but it can live comfortably in pools which are foul with decomposing animal and vegetable matter. In partially dried-up and foul waterholes, full of dead fishes of various kinds, Neoceratodus has been found vigorous and lively. Unless we take the view, which is *possible*, that the swim-bladder of fishes was originally a lung, the mudfishes are learning to breathe dry air. They illustrate evolution agoing.

The herring-gull is by nature a fish-eater; but of recent years, in some parts of Britain, it has been becoming in the summer months more and more of a vegetarian, scooping out the turnips, devouring potatoes, settling on the sheaves in the harvest field and gorging itself with grain. Similar experiments, usually less striking, are known in many birds; but the most signal illustration is that of the kea or Nestor parrot of New Zealand, which has taken to lighting on the loins of the sheep, tearing away the fleece, cutting at the skin, and gouging out fat. Now the parrot belongs to a vegetarian or frugivorous stock, and this change of diet in the relatively short time since sheep-ranches were established in New Zealand is very striking. Here, since we know the dates, we may speak of evolution going on under our eyes. It must be remembered that variations in habit may give an animal a new opportunity to test variations in structure which arise mysteriously from within, as expressions of germinal changefulness rather than as imprints from without. For of the transmissibility of the latter there is little secure evidence.

Experiments in Locomotion.

It is very interesting to think of the numerous types of locomotion which animals have discovered—pulling and punting, sculling and rowing, and of the changes that are rung on these four main methods. How striking is the case of the frilled lizard (Chlamydosaurus) of Australia, which at the present time is, as it were,

experimenting in bipedal progression—always a rather eventful thing to do. It gets up on its hind-legs and runs totteringly for a few feet, just like a baby learning to walk.

THE WATER-SPIDER

The spider is seen just leaving its diving-bell to ascend to the surface to capture air. The spider jerks its body and legs out at the surface and then dives— —carrying with it what looks like a silvery air-bubble—air entangled in the hair.

The spider reaches its air-dome. Note how the touch of its legs indents the inflated balloon. Running down the side of the nest, the spider —brushes off the air at the entrance, and the bubble ascends into the silken balloon.

Photos: J. J. Ward, F.E.S.

How beautiful is the adventure which has led our dipper or water-ouzel—a bird allied to the wrens—to try walking and flying under water!

How admirable is the volplaning of numerous parachutists—"flying fish," "flying frog," "flying dragon," "flying phalanger," "flying squirrel," and more beside, which take great leaps through the air. For are these not the splendid failures that might have succeeded in starting new modes of flight?

Most daring of all, perhaps, are the aerial journeys undertaken by many small spiders. On a breezy morning, especially in the autumn, they mount on gateposts and palings and herbage, and, standing with their head to the wind, pay out three or four long threads of silk. When the wind tugs at these threads, the spinners let go, and are borne, usually back downwards, on the wings of the wind from one parish to another. It is said that if the wind falls they can unfurl more sail, or furl if it rises. In any case, these wingless creatures make aerial journeys. When tens of thousands of the used threads sink to earth, there is a "shower of gossamer." On his *Beagle* voyage Darwin observed that vast numbers of small gossamer spiders were borne on to the ship when it was sixty miles distant from the land.

It is impossible, we must admit, to fix dates, except in a few cases, relatively recent; but there is a smack of modernity in some striking devices which we can observe in operation to-day. Thus no one will dispute the statement that spiders are thoroughly terrestrial animals breathing dry air, but we have the fact of the water-spider conquering the under-water world. There are a few spiders about the sea-shore, and a few that can survive douching with fresh water, but the particular case of the true water-spider, *Argyroneta natans*, stands by itself because the creature, as regards the female at least, has *conquered* the sub-aquatic environment. A flattish web is woven, somehow, underneath the water, and pegged down by threads of silk. Along a special vertical line the mother spider ascends to the surface and descends again, having entangled air in the hairs of her body. She brushes off this air underneath her web, which is thereby buoyed up into a sort of dome. She does this over and over again, never getting wet all the time, until the domed web has become like a diving-bell, full of dry air. In this eloquent anticipation of man's rational device, this creature—far from being endowed with reason—lays her eggs and looks after her young. The general significance of the facts is that when competition is keen, a new area of exploitation is a promised land. Thus spiders have spread over all the earth except the polar areas. But here is a spider with some spirit of adventure, which has endeavoured, instead of trekking, to find a new corner near at home. It has tackled a problem surely difficult for a terrestrial animal, the problem of living in great part under water, and it has solved it in a manner at once effective and beautiful.

New Devices.

We have given but a few representative illustrations of a great theme. When we consider the changefulness of living creatures, the transformations of cultivated plants and domesticated animals, the gradual alterations in the fauna of a country, the search after new haunts, the forming of new habits, and the discovery of many inventions, are we not convinced that Evolution is going on? And why should it stop?

In conclusion.

VII

THE DAWN OF MIND

IN the story of evolution there is no chapter more interesting than the emergence of mind in the animal kingdom. But it is a difficult chapter to read, partly because "mind" cannot be seen or measured, only *inferred* from the outward behaviour of the creature, and partly because it is almost impossible to avoid reading ourselves into the much simpler animals.

Two Extremes to be avoided.

The one extreme is that of uncritical generosity which credits every animal, like Brer Rabbit—who, by the way, was the hare—with human qualities. The other extreme is that of thinking of the animal as if it were an automatic machine, in the working of which there is no place or use for mind. Both these extremes are to be avoided.

When Professor Whitman took the eggs of the Passenger Pigeon (which became extinct not long ago with startling rapidity) and placed them a few inches to one side of the nest, the bird looked a little uneasy and put her beak under her body as if to feel for something that was not there. But she did not try to retrieve her eggs, close at hand as they were. In a short time she flew away altogether. This shows that the mind of the pigeon is in some respects very different from the mind of man. On the other hand, when a certain clever dog, carrying a basket of eggs, with the handle in his mouth, came to a stile which had to be negotiated, he laid the basket on the ground, pushed it gently through a low gap to the other side, and then took a running leap over. We dare not talk of this dog as an automatic machine.

Photo: O. J. Wilkinson.

JACKDAW BALANCING ON A GATEPOST.

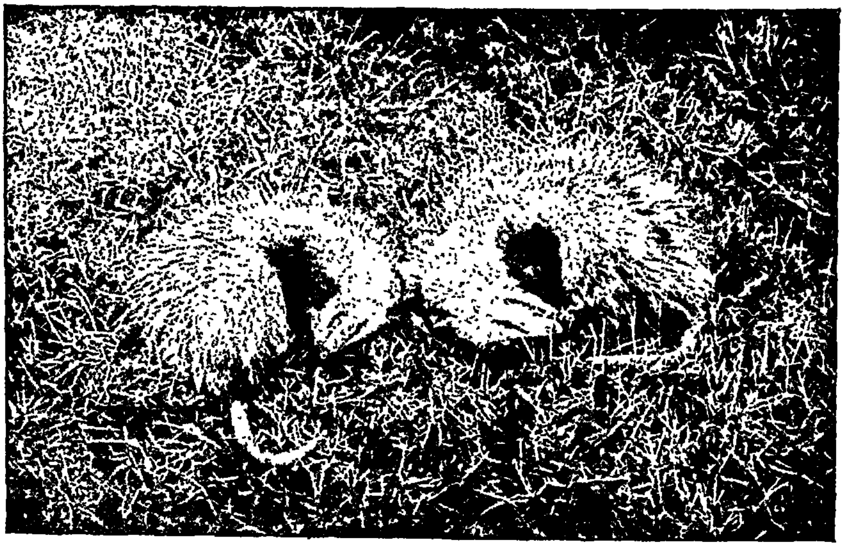
The jackdaw is a big-brained, extremely alert, very educable, loquacious bird.

A Caution in regard to Instinct.

In studying the behaviour of animals, which is the only way of getting at their mind, for it is only of our own mind that we have direct knowledge, it is essential to give prominence to the fact that there has been throughout the evolution of living creatures a strong tendency to enregister or engrain capacities of doing things effectively. Thus certain abilities come to be inborn; they are parts of the inheritance, which will express themselves

whenever the appropriate trigger is pulled. The newly born child does not require to learn its breathing movements, as it afterwards requires to learn its walking movements. The ability to go through the breathing movements is inborn, engrained, enregistered.

In other words, there are hereditary pre-arrangements of nerve-cells and muscle-cells which come into activity almost as easily as the beating of the heart. In a minute or two the new-born pigling creeps close to its mother and sucks milk. It has not to learn how to do this any more than we have to learn to cough or sneeze. Thus animals have many useful ready-made, or almost ready-made, capacities of doing apparently clever things. In simple cases of these inborn pre-arrangements we speak of reflex actions; in more complicated cases, of instinctive behaviour. Now the caution is this, that while these inborn capacities usually work well in natural conditions, they sometimes work badly when the ordinary routine is disturbed. We see this when a pigeon continues sitting for many days on an empty nest, or when it fails to retrieve its eggs only two inches away. But it would be a mistake to call the pigeon, because of this, an unutterably stupid bird. We have only to think of the achievements of homing pigeons to know that this cannot be true. We must not judge animals in regard to those kinds of behaviour which have been handed over to instinct, and go badly agee when the normal routine is disturbed. In ninety-nine cases out of a hundred the enregistered instinctive capacities work well, and the advantage of their becoming stereotyped was to leave the animal more free for adventures at a higher level. Being "a slave of instinct" may give the animal a security that enables it to discover some new home or new food or new joy. Somewhat in the same way, a man of methodical habits, which he has himself established, may gain leisure to make some new departure of racial profit.



From Ingersoll's "The Wit of the Wild."

TWO OPOSSUMS FEIGNING DEATH.

The Opossums are mainly arboreal marsupials, insectivorous and carnivorous, confined to the American Continent from the United States to Patagonia. Many have no pouch and carry their numerous young ones on their back, the tail of the young twined round that of the mother. The opossums are agile, clever creatures, and famous for "playing 'possum," lying inert just as if they were dead.

When we draw back our finger from something very hot, or shut our eye to avoid a blow from a rebounding branch, we do not will the action; and this is more or less the case, probably, when a young mammal sucks its mother for the first time. Some Mound-birds of Celebes lay their eggs in warm volcanic ash by the shore of the sea, others in a great mass of fermenting vegetation; it is inborn in the newly hatched bird to struggle out as quickly as it can from such a strange nest, else it will suffocate. If it stops struggling too soon, it perishes, for it seems that

and changes of pressure in the water. The skin responds to pressures, the ear to vibrations of high frequency; the lateral line is between the two in its function.

The brain of the ordinary bony fish is at a very low level. Thus the cerebral hemispheres, destined to become more and more the seat of intelligence, are poorly developed. In gristly fishes, like skates and sharks, the brain is much more promising. But although the state of the brain does not lead one to expect very much from a bony fish like trout or eel, haddock or herring, illustrations are not wanting of what might be called pretty pieces of behaviour. Let us select a few cases.

Interesting Ways of Fishes.

The three-spined and two-spined sticklebacks live equally well in fresh or salt water; the larger fifteen-spined stickleback is entirely marine. In all three species the male fish makes a nest, in fresh or brackish water in the first two cases, in shore-pools in the third case. The little species use the leaves and stems of water-plants; the larger species use seaweed and zoophyte. The leaves or fronds are entangled together and fastened by glue-like threads, secreted, strange to say, by the kidneys. It is just as if a temporary diseased condition had been regularised and turned to good purpose. Going through the nest several times, the male makes a little room in the middle. Partly by coercion and partly by coaxing he induces a female—first one and then another—to pass through the nest with two doors, depositing eggs during her short sojourn. The females go their way, and the male mounts guard over the nest. He drives off intruding fishes much bigger than himself. When the young are hatched, the male has for a time much to do, keeping his charges within bounds until they are able to move about with agility. It seems that sticklebacks are short-lived fishes, probably breeding only once; and it is reasonable to suppose that their success as a race depends to some extent on the paternal care. Now if we could believe that the nesting behaviour had appeared suddenly in its present form, we should be inclined to credit the fish with considerable mental ability. But we are less likely to be so generous if we reflect that the routine has been in all likelihood the outcome of a long racial process of slight improvements and critical testings. The secretion of the glue probably came about as a pathological variation; its utilisation was perhaps discovered by accident; the types that had wit enough to take advantage of this were most successful; the routine became enregistered hereditarily. The stickleback is not so clever as it looks.

The Stickleback's Nest.

MALE OF THREE-SPINED STICKLEBACK, MAKING A NEST OF WATER-WEED, GLUED TOGETHER BY VISCID THREADS SECRETED FROM THE KIDNEYS AT THE BREEDING SEASON.

The Mind of a Minnow.

To find solid ground on which to base an appreciation of the behaviour of fishes, it is necessary to experiment, and we may refer to Miss Gertrude White's interesting work on American min-

nows and sticklebacks. After the fishes had become quite at home in their artificial surroundings, their lessons began. Cloth packets, one of which contained meat and the other cotton, were suspended at opposite ends of the aquarium. The mud-minnows did not show that they perceived either packet, though they swam close by them; the sticklebacks were intrigued at once. Those that went towards the packet containing meat darted furiously upon it and pulled at it with great excitement. Those that went towards the cotton packet turned sharply away when they were within about two inches off. They then perceived what those at the other end were after and joined them — a common habit amongst fishes. Although the minnows were not interested in the tiny "bags of mystery," they were even more alert than the sticklebacks in perceiving moving objects in or on the water, and there is no doubt that both these shallow-water species discover their food largely by sense of sight.

A FEMALE STICKLEBACK ENTERS THE NEST WHICH THE MALE HAS MADE, LAYS THE EGGS INSIDE, AND THEN DEPARTS.

In many cases two or three females use the same nest, the stickleback being polygamous. Above the nest the male, who mounts guard, is seen driving away an intruder.

The next set of lessons had to do with colour-associations. The fishes were fed on minced snail, chopped earthworm, fragments of liver, and the like, and the food was given to them from the end of forceps held above the surface of the water, so that the fishes could not be influenced by smell. They had to leap out of the water to take the food from the forceps. Discs of coloured cardboard were slipped over the end of the forceps, so that what the fishes saw was a morsel of food in the centre of a coloured disc. After a week or so of preliminary training, they were so well accustomed to the coloured discs that the presentation of one served as a signal for the fishes to dart to the surface and spring out of the water. When baits of paper were substituted for the food, the fishes continued to jump at the discs. When, however, a blue disc was persistently used for the paper bait and a red disc for the real food, or *vice versa*, some of the minnows learned to discriminate infallibly between shadow and substance, both when these were presented alternately and when they were presented simultaneously. This is not far from the dawn of mind.

In the course of a few lessons, both minnows and sticklebacks learned to associate particular colours with food, and other associations were also formed. A kind of larva that a minnow could make nothing of after repeated trials was subsequently ignored. The approach of the experimenter or anyone else soon began to serve as a food-signal. There can be no doubt that in the ordinary life of fishes there is a process of forming useful associations and suppressing useless responses. Given an inborn repertory of profitable movements that require no training, given the power of forming associations such as those we have illustrated, and given a consider-

able degree of sensory alertness along certain lines, fishes do not require much more. And in truth they have not got it. Moving with great freedom in three dimensions in a medium that supports them and is very uniform and constant, able in most cases to get plenty of food without fatiguing exertions and to dispense with it for considerable periods if it is scarce, multiplying usually in great abundance so that the huge infantile mortality hardly counts, rarely dying a natural death but usually coming with their strength unabated to a violent end, fishes hold their own in the struggle for existence without much in the way of mental endowment. Their brain has more to do with motion than with mentality, and they have remained at a low psychical level.

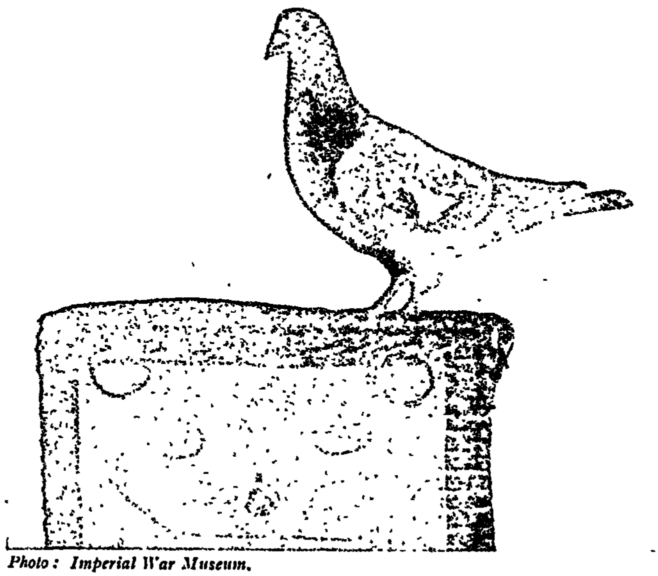


Photo: Imperial War Museum.

HOMING PIGEON.

A blue chequer hen, which during the War (in September of 1918) flew 22 miles in as many minutes, saving the crew of an aeroplane in difficulties.

Yet just as we should greatly misjudge our own race if we confined our attention to everyday routine, so in our total, as distinguished from our average, estimate of fishes, we must remember the salmon surmounting the falls, the wary trout eluding the angler's skill, the common mud-skipper (Periophthalmus) of many tropical shores which climbs on the rocks and the roots of the mangrove-trees, or actively hunts small shore-animals. We must remember the adventurous life-history of the eel and the quaint ways in which some fishes, males especially, look after their family. The male sea-horse puts the eggs in his breast-pocket; the male Kurtus carries them on the top of his head; the cock-paidle or lumpsucker guards them and aerates them in a corner of a shore-pool.

§ 3

The Mind of Old Amphibians.

Towards the end of the age of the Old Red Sandstone or Devonian, a great step in evolution was taken—the emergence of Amphibians. The earliest representatives had fish-like characters even more marked than those which may be discerned in the tadpoles of our frogs and toads, and there is no doubt that amphibians sprang from a fish stock. But they made great strides, associated in part with their attempts to get out of the water on to dry land. From fossil forms we cannot say much in regard to soft parts; but if we consider the living representatives of the class, we may credit amphibians with such important acquisitions as fingers and toes, a three-chambered heart, true ventral lungs, a drum to the ear, a mobile tongue, and vocal cords. When animals began to be able to grasp an object and when they began to be able to utter sufficient sounds, two new doors were opened. Apart from insects, whose instrumental music had probably begun before the end of the Devonian age, amphibians were the first animals to have a voice. The primary meaning of this voice was doubtless, as it is to-day in our frogs, a sex-call; but it was the beginning of what was destined to play a very important part in the evolution of the mind. In the course of ages the significance of the voice broadened out; it became a parental call; it became an infant's cry. Broadening still, it became a very useful means of recognition among kindred, especially in the dark and in the intricacies of the forest. Ages passed, and the voice rose on another turn of the evolutionary

spiral to be expressive of particular emotions beyond the immediate circle of sex—emotions of joy and of fear, of jealousy and of contentment. Finally, we judge, the animal—perhaps the bird was first—began to give utterance to particular "words," indicative not merely of emotions, but of particular things with an emotional halo, such as "food," "enemy," "home." Long afterwards, words became *in man* the medium of reasoned discourse. Sentences were made and judgments expressed. But was not the beginning in the croaking of Amphibia?

Senses of Amphibians.

Frogs have good eyes, and the toad's eyes are "jewels." There is evidence of precise vision in the neat way in which a frog catches a fly, flicking out its tongue, which is fixed in front and loose behind. There is also experimental proof that a frog discriminates between red and blue, or between red and white, and an interesting point is that while our skin is sensitive to heat rays but not to light, the skin of the frog answers back to light rays as well. Professor Yerkes experimented with a frog which had to go through a simple labyrinth if it wished to reach a tank of water. At the first alternative between two paths, a red card was placed on the wrong side and a white one on the other. When the frog had learned to take the correct part, marked by the white card, Prof. Yerkes changed the cards. The confusion of the frog showed how thoroughly it had learned its lesson.

We know very little in regard to sense of smell or taste in amphibians; but the sense of hearing is well developed, more developed than might be inferred from the indifference that frogs show to almost all sounds except the croaking of their kindred and splashes in the water.

The toad looks almost sagacious when it is climbing up a bank, and some of the tree-frogs are very alert; but there is very little that we dare say about the amphibian mind. We have mentioned that frogs may learn the secret of a simple maze, and toads sometimes make for a particular spawning-pond from a considerable distance. But an examination of their brains, occupying a relatively small part of the broad, flat skull, warns us not to expect much intelligence. On the other hand, when we take frogs along a line that is very vital to them, namely, the discrimination of palatable and un-

Photo: Imperial War Museum.

CARRIER PIGEON.

Carrier pigeons were much used in the War to carry messages. The photograph shows how the message is fixed to the carrier pigeon's leg, in the form of light rings.

palatable insects, we find, by experiment, that they are quick to learn and that they remember their lessons for many days. Frogs sometimes deposit their eggs in very unsuitable pools of water; but perhaps that is not quite so stupid as it looks. The egg-laying is a matter that has been, as it were, handed over to instinctive registration.

Experiments in Parental Care.

It must be put to the credit of amphibians that they have made many experiments in methods of parental care, as if they were feeling their way to new devices. A common frog lays her clumps of eggs in the cradle of the water, sometimes far over a thousand together; the toad winds two long strings round and between water-weeds; and in both cases that is all. There is no parental care, and the prolific multiplication covers the enormous infantile mortality. This is the spawning solution of the problem of securing the continuance of the race. But there is another solution, that of parental care associated with an economical reduction of the number of eggs. Thus the male of the Nurse-Frog (Alytes), not uncommon on the Continent, fixes a string of twenty to fifty eggs to the upper part of his hind-legs, and retires to his hole, only coming out at night to get some food and to keep up the moisture about the eggs. In three weeks, when the tadpoles are ready to come out, he plunges into the pond and is freed from his living burden and his family cares. In the case of the thoroughly aquatic Surinam Toad (Pipa), the male helps to press the eggs, perhaps a hundred in number, on to the back of the female, where each sinks into a pocket of skin with a little lid. By and by fully formed young toads jump out of the pockets.

Photo: James's Press Agency.

YELLOW-CROWNED PENGUIN.

Notice the flightless wings turned into flippers, which are often flapped very vigorously. The very strong feet are also noteworthy. Penguins are mostly confined to the Far South.

In the South American tree-frogs called Nototrema there is a pouch on the back of the female in which the eggs develop, and it is interesting to find that in some species what come out are ordinary tadpoles, while in other species the young emerge as miniatures of their parents. Strangest of all, perhaps, is the case of Darwin's Frog (Rhinoderma of Chili), where the young, about ten to fifteen in number, develop in the male's croaking-sacs, which become in consequence enormously distended. Eventually the strange spectacle is seen of miniature frogs jumping out of their father's mouth. Needless to say, we are not citing these methods of parental care as examples of intelligence; but perhaps they correct the impression of amphibians as a rather humdrum race. Whatever be the mental aspect of the facts, there has certainly been some kind of experimenting, and the increase of parental care, so marked in many amphibians, with associated reduction of the number of offspring is a finger-post on the path of progress.

§ 4

We speak of the wisdom of the serpent; but it is not very easy to justify the phrase. Among

all the multitude of reptiles—snakes, lizards, turtles, and crocodiles, a motley crowd—we cannot see much more than occasional traces of intelligence. The inner life remains a tiny rill.

The Reptilian Mind.

No doubt many reptiles are very effective; but it is an instinctive rather than an intelligent efficiency. The well-known "soft-shell" tortoise of the United States swims with powerful strokes and runs so quickly that it can hardly be overtaken. It hunts vigorously for crayfish and insect larvæ in the rivers. It buries itself in the mud when cold weather comes. It may lie on a floating log, ready to slip into the water at a moment's notice; it may bask on a sunny bank or in the warm shallows. Great wariness is shown in choosing times and places for egg-laying. The mother tramps the earth down upon the buried eggs. All is effective. Similar statements might be made in regard to scores of other reptiles; but what we see is almost wholly of the nature of instinctive routine, and we get little glimpse of more than efficiency and endeavour.

In a few cases there is proof of reptiles finding their way back to their homes from a considerable distance, and recognition of persons is indubitable. Gilbert White remarks of his tortoise: "Whenever the good old lady came in sight who had waited on it for more than thirty years, it always hobbled with awkward alacrity towards its benefactress, while to strangers it was altogether inattentive." Of definite learning there are a few records. Thus Professor Yerkes studied a sluggish turtle of retiring disposition, taking advantage of its strong desire to efface itself. On the path of the darkened nest of damp grass he interposed a simple maze in the form of a partitioned box. After wandering about constantly for thirty-five minutes the turtle found its way through the maze by chance. Two hours afterwards it reached the nest in fifteen minutes; and after another interval of two hours it only required five minutes. After the third trial, the routes became more direct, there was less aimless wandering. The time of the twentieth trial was forty-five seconds; that of the thirtieth,

Photo: Cagcombe & Co.

PENGUINS ARE "A PECULIAR PEOPLE."

Their wings have been turned into flippers for swimming in the sea and tobogganing on snow. The penguins come back over hundreds of miles of trackless waste to their birthplace, where they breed. When they reach the Antarctic shore they walk with determination to a suitable site, often at the top of a steep cliff. Some species waddle 130 steps per minute, 6 inches per step, two-thirds of a mile per hour.

forty seconds. In the thirtieth case, the path followed was quite direct, and so it was on the fiftieth trip, which only required thirty-five seconds. Of course, the whole thing did not amount to very much; but there was a definite learning, *a learning from experience*, which has played an important part in the evolution of animal behaviour.

Comparing reptiles with amphibians, we may recognise an increased masterliness of behaviour and a hint of greater plasticity. The records of observers who have made pets of reptiles suggest that the life of feeling or emotion is growing stronger, and so do stories, if they can be accepted, which suggest the beginning of conjugal affection.

The error must be guarded against of interpreting in terms of intelligence what is merely the outcome of long-continued structural adaptation. When the limbless lizard called the Slow-worm is suddenly seized by the tail, it escapes by surrendering the appendage, which breaks across a preformed weak plane. But this is a reflex action, not a reflective one. It is comparable to our sudden withdrawal of our finger from a very hot cinder. The Egg-eating African snake Dasypeltis gets the egg of a bird into its gullet unbroken, and cuts the shell against downward-projecting sharp points of the vertebræ. None of the precious contents is lost and the broken "empties" are returned. It is admirable, indeed unsurpassable; but it is not intelligent.

Photo: W. S. Berridge.

HARPY-EAGLE.

"Clean and dainty and proud as a Spanish Don."

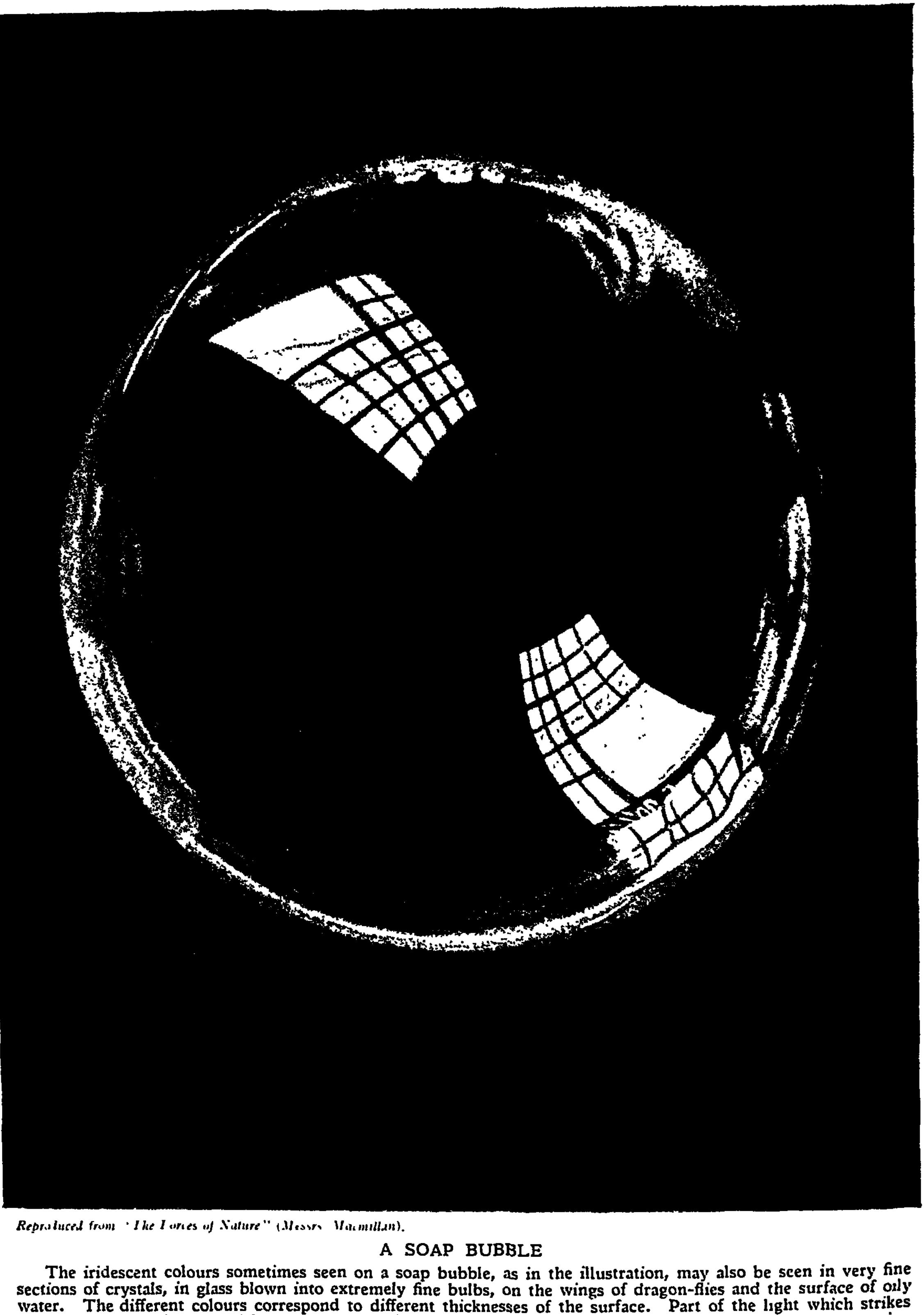
It is an arboreal and cliff-loving bird, feeding chiefly on mammals, very fierce and strong. The under parts are mostly white, with a greyish zone on the chest. The upper parts are blackish-grey. The harpy occurs from Mexico to Paraguay and Bolivia.

§ 5

Mind in Birds.

Sight and hearing are highly developed in birds, and the senses, besides pulling the triggers of inborn efficiencies, supply the raw materials for intelligence. There is some truth, though not the whole truth, in the old philosophical dictum, that there is nothing in the intellect which was not previously in the senses. Many people have admired the certainty and alacrity with which gulls pick up a fragment of biscuit from the white wake of a steamer, and the incident is characteristic. In their power of rapidly altering the focus of the eye, birds are unsurpassed.

To the sense of sight in birds, the sense of hearing comes a good second. A twig breaks under our feet, and out sounds the danger-call of the bird we were trying to watch. Many young birds, like partridges, respond when two or three hours old to the anxious warning note of the parents, and squat motionless on the ground, though other sounds, such as the excited clucking of a foster-mother hen, leave them indifferent. They do not know what they are doing when they squat; they are obeying the living hand of the past which is within them. Their behaviour is instinctive. But the present point is the discriminating quality of the sense of hearing;



Reproduced from "The Forces of Nature" (Messrs. Macmillan).

A SOAP BUBBLE

The iridescent colours sometimes seen on a soap bubble, as in the illustration, may also be seen in very fine sections of crystals, in glass blown into extremely fine bulbs, on the wings of dragon-flies and the surface of oily water. The different colours correspond to different thicknesses of the surface. Part of the light which strikes these thin coatings is reflected from the upper surface, but another part of the light penetrates the transparent coating and is reflected from the lower surface. It is the mixture of these two reflected rays, their " interference " as it is called, which produces the colours observed. The " black spots " on a soap bubble are the places where the soapy film is thinnest. At the black spots the thickness of the bubble is about the twenty-five-thousandth part of an inch. If the whole bubble were as thin as this it would be completely invisible.

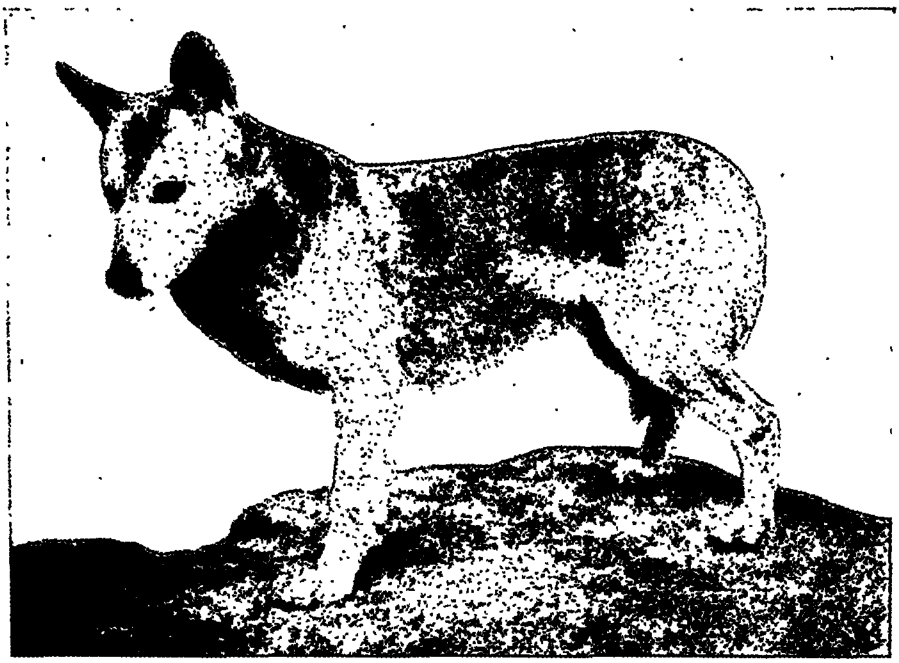


Photo: W. S. Berridge, F.Z.S.

THE DINGO OR WILD DOG OF AUSTRALIA, PERHAPS AN INDIGENOUS WILD SPECIES, PERHAPS A DOMESTICATED DOG THAT HAS GONE WILD OR FERAL.

It does much harm in destroying sheep. It is famous for its persistent "death-feigning," for an individual has been known to allow part of its skin to be removed, in the belief that it was dead, before betraying its vitality.

and that is corroborated by the singing of birds. It is emotional art, expressing feelings in the medium of sound. On the part of the females, who are supposed to listen, it betokens a cultivated ear.

As to the other senses, touch is not highly developed except about the bill, where it reaches a climax in birds like the woodcock, which probe for unseen earthworms in the soft soil. Taste seems to be poorly developed, for most birds bolt their food, but there is sometimes an emphatic rejection of unpalatable things, like toads and caterpillars. Of smell in birds little is known, but it has been proved to be present in certain cases, e.g. in some nocturnal birds of prey. It seems certain that it is by sight, not by smell, that the eagles gather to the carcass; but perhaps there is more smell in birds than they are usually credited with. One would like to experiment with the oil from the preen gland of birds to see whether the scent of this does not help in the recognition of kin by kin at night or amid the darkness of the forest. There may be other senses in birds, such as a sense of temperature and a sense of balance; but no success has attended the attempts made to demonstrate a magnetic sense, which has been impatiently postulated by students of bird migration in order to "explain" how the birds find their way. The big fact is that in birds there are two widely open gateways of knowledge, the sense of sight and the sense of hearing.

Instinctive Aptitudes.

Many a young water-bird, such as a coot, swims right away when it is tumbled into water for the first time. So chicks peck without any learning or teaching, very young ducklings catch small moths that flit by, and young plovers lie low when the danger-signal sounds. But birds seem strangely limited as regards many of these instinctive capacities—limited when compared with the "little-brained" ants and bees, which have from the first such a rich repertory of ready-made cleverness. The limitation in birds is of great interest, for it means that intelligence is coming to its own and is going to take up the reins at many corners of the daily round. Professor Lloyd Morgan observed that his chickens incubated in the laboratory had no instinctive awareness of the significance of their mother's cluck when she was brought

WOODPECKER, HAMMERING AT A COTTON-REEL ATTACHED TO A TREE.

Notice how the stiff tail-feathers braced against the stem help the bird to cling on with its toes. The original hole, in which this woodpecker inserted nuts for the purposes of cracking the shell and extracting the kernel, is seen towards the top of the tree. But the taker of the photograph tied on a hollowed-out cotton-reel as a receptacle for a nut, and it was promptly discovered and used by the bird.

outside the door. Although thirsty and willing to drink from a moistened finger-tip, they did not instinctively recognise water, even when they walked through a saucerful. Only when they happened to peck their toes as they stood in the water did they appreciate water as the stuff they wanted, and raise their bills up to the sky. Once or twice they actually stuffed their crops with " worms " of red worsted!

Instinctive aptitudes, then, the young birds have, but these are more limited than in ants, bees, and wasps; and the reason is to be found in the fact that the brain is now evolving on the tack of what Sir Ray Lankester has called " educability." Young birds *learn* with prodigious rapidity; the emancipation of the mind from the tyranny of hereditary obligations has begun. Young birds make mistakes, like the red worsted mistake, but they do not make the same mistakes often. They are able to profit by experience in a very rapid way. We do not mean that creatures of the little-brain type, like ants, bees, and wasps, are unable to profit by experience or are without intelligence. There are no such hard-and-fast lines. We mean that in the ordinary life of insects the enregistered instinctive capacities are on the whole sufficient for the occasion, and that intelligent educability is very slightly developed. Nor do we mean that birds are quite emancipated from the tyranny of engrained instinctive obligations, and can always " ring up " intelligence in a way that is impossible for the stereotyped bee. The sight of a pigeon brooding on an empty nest, while her two eggs lie disregarded only a couple of inches away, is enough to show that along certain lines birds may find it impossible to get free from the trammels of instinct. The peculiar interest of birds is that they have many instincts and yet a notable power of learning intelligently.

Intelligence co-operating with Instinct.

Professor Lloyd Morgan was foster-parent to two moorhens which grew up in isolation from their kindred. They swam instinctively, but they would not dive, neither in a large bath nor in a current. But it happened one day when one of these moorhens was swimming in a pool on a Yorkshire stream, that a puppy came barking down the bank and made an awkward feint towards the young bird. In a

moment the moorhen dived, disappeared from view, and soon partially reappeared, his head just peeping above the water beneath the overhanging bank. This was the first time the bird had dived, and the performance was absolutely true to type.

There can be little doubt as to the meaning of this observation. The moorhen has an hereditary or instinctive capacity for swimming and diving, but the latter is not so easily called into activity as the former. The particular moorhen in question had enjoyed about two months of swimming experience, which probably counted for something, but in the course of that experience nothing had pulled the trigger of the diving capacity. On an eventful day the young moorhen saw and heard the dog; it was emotionally excited; it probably did to some extent intelligently appreciate a novel and meaningful situation. Intelligence co-operated with instinct, and the bird dived appropriately.

Birds have inborn predispositions to certain effective ways of pecking, scratching, swimming, diving, flying, crouching, lying low, nest-building, and so on; but they are marked off from the much more purely instinctive ants and bees by the extent to which individual "nurture" seems to mingle with the inherited "nature." The two together result in the fine product which we call the bird's behaviour. After Lloyd Morgan's chicks had tried a few conspicuous and unpalatable caterpillars, they had no use for any more. They learned in their early days with prodigious rapidity, illustrating the deep difference between the "big-brain" type, relatively poor in its endowment of instinctive capacities, but eminently "educable," and the "little-brain" type, say, of ants and bees, richly endowed with instinctive capacities, but very far from being quick or glad to learn. We owe it to Sir Ray Lankester to have made it clear that these two types of brain are, as it were, on different tacks of evolution, and should not be directly pitted against one another. The "little-brain" type makes for a climax in the ant, where instinctive behaviour reaches a high degree of perfection; the "big-brain" type reaches its climax in horse and dog, in

THE BEAVER.

The beaver will gnaw through trees a foot in diameter; to save itself more trouble than is necessary, it will stop when it has gnawed the trunk till there is only a narrow core left, having the wit to know that the autumn gales will do the rest.

elephant and monkey. The particular interest that attaches to the behaviour of birds is in the combination of a good deal of instinct with a great deal of intelligent learning. This is well illustrated when birds make a nest out of new materials or in some quite novel situation. It is clearly seen when birds turn to some new kind of food, like the Kea parrot, which attacks the sheep in New Zealand.

Some young woodpeckers are quite clever in opening fir cones to get at the seeds, and this might be hastily referred to a well-defined hereditary capacity. But the facts are that the parents bring their young ones first the seeds themselves, then partly opened cones, and then intact ones. There is an educative process, and so it is in scores of cases.

Using their Wits.

When the Greek eagle lifts the Greek tortoise in its talons, and lets it fall from a height so that the strong carapace is broken and the flesh exposed, it is making intelligent use of an expedient. Whether it discovered the expedient by experimenting, as is possible, or by chance, as is more likely, it uses it intelligently. In the same way herring-gulls lift sea-urchins and clams in their bills, and let them fall on the rocks so that the shells are broken. In the same way rooks deal with freshwater mussels.

The Thrush's Anvil.

A very instructive case is the behaviour of the song-thrush when it takes a wood-snail in its beak and hammers it against a stone, its so-called anvil. To a young thrush, which she had brought up by hand, Miss Frances Pitt offered some wood-snails, but it took no interest in them until one put out its head and began to move about. The bird then pecked at the snail's horns, but was evidently puzzled when the creature retreated within the shelter of the shell. This happened over and over again, the thrush's inquisitive interest increasing day by day. It pecked at the shell and even picked it up by the lip, but no real progress was made till the sixth day, when the thrush seized the snail and beat it on the ground as it would a big worm. On the same day it picked up a shell and knocked it repeatedly against a stone, trying first one snail and then another. After fifteen minutes' hard work, the thrush managed to break one, and after that it was all easy. A certain predisposition to beat things on the ground was doubtless present, but the experiment showed that the use of an anvil could be arrived at by an untutored bird. After prolonged trying it found out how to deal with a difficult situation. It may be said that in more natural conditions this might be picked up by imitation, but while this is quite possible, it is useful to notice that experiments with animals lead us to doubt whether imitation counts for nearly so much as used to be believed.

§ 6

The Mind of the Mammal.

When we watch a collie at a sheep-driving competition, or an elephant helping the forester, or a horse shunting waggons at a railway siding, we are apt to be too generous to the mammal mind. For in the cases we have just mentioned, part of man's mind has, so to speak, got into the animal's. On the other hand, when we study rabbits and guinea-pigs, we are apt to be too stingy, for these rodents are under the average of mammals, and those that live in domestication illustrate the stupefying effect of a too sheltered life. The same applies to domesticated sheep contrasted with wild sheep, or even with their own lambs. If we are to form a sound judgment on the intelligence of mammals we must not attend too much to those that have profited by man's training, nor to those whose mental life has been dulled by domestication.

Instinctive Aptitudes.

What is to be said of the behaviour of beavers who gnaw the base of a tree with their chisel-edged teeth till only a narrow core is left—to snap in the first gale, bringing the useful branches down to the ground? What is to be said of the harvest-mouse constructing its nest, or of the squirrel making cache after cache of nuts? These and many similar pieces of behaviour are fundamentally instinctive, due to inborn predispositions of nerve-cells and muscle-cells. But in mammals they seem to be often attended by a certain amount of intelligent attention, saving the creature from the tyranny of routine so marked in the ways of ants and bees.

Besides instinctive aptitudes, which are exhibited in almost equal perfection by all the members of the same species, there are

Photo: F. R. Hinkins & Son.

THE THRUSH AT ITS ANVIL.

The song-thrush takes the snail's shell in its bill, and knocks it against a stone until it breaks, making the palatable flesh available. Many broken shells are often found around the anvil.

acquired dexterities which depend on individual opportunities. They are also marked by being outside and beyond ordinary routine —not that any rigorous boundary-line can be drawn. We read that at Mathura on the Jumna doles of food are provided by the piety of pilgrims for the sacred river-tortoises, which are so crowded when there is food going that their smooth carapaces form a more or less continuous raft across the river. On that unsteady slippery bridge the Langur monkeys (*Semnopithecus entellus*) venture out and in spite of vicious snaps secure a share of the booty. This picture of the monkeys securing a footing on the moving mass of turtle-backs is almost a diagram of sheer dexterity. It illustrates the spirit of adventure, the will to experiment, which is, we believe, the main motive-force in new departures in behaviour.

Sheer Dexterity.

A bull-terrier called Jasper, studied by Prof. J. B. Watson, showed great power of associating certain words with certain actions. From a position invisible to the dog the owner would give certain commands, such as "Go into the next room and bring me a paper lying on the floor." Jasper did this at once, and a score of similar things.

Power of Association.

Lord Avebury's dog Van was accustomed to go to a box containing a small number of printed cards and select the card TEA or OUT, as the occasion suggested. It had established an association between certain black marks on a white background and the gratification of certain desires. It is probable that some of the extraordinary things horses and dogs have been known to do in the way of stamping a certain number of times in supposed indication of an answer to an arithmetical question (in the case of horses), or of the name of an object drawn (in the case of dogs), are dependent on clever associations established by the teacher between minute signs and a number of stampings. What is certain is that mammals have in varying degrees a strong power of establishing associations. There is often some delicacy in the association established. Everyone knows of cases where a dog, a cat, or a horse will remain quite uninterested, to all appearance, in its owner's movements until some little detail, such as taking a key from its peg, pulls the

trigger. Now the importance of this in the wild life of the fox or the hare, the otter or the squirrel, is obviously that the young animals learn to associate certain sounds in their environment with definite possibilities. They have to learn an alphabet of woodcraft, the letters of which are chiefly sounds and scents.

Photo: Lafayette.

ALSATIAN WOLF-DOG.

An animal of acute senses and great intelligence. It was of great service in the war. (The dog shown, Arno von Indetal, is a trained police dog and did service abroad during the war.)

The Dancing Mouse as a Pupil.

The dancing or waltzing mouse is a Japanese variety with many peculiarities, such as having only one of the three semicircular canals of the ear well developed. It has a strong tendency to waltz round and round in circles without sufficient cause and to trip sideways towards its dormitory instead of proceeding in the orthodox head-on fashion. But this freak is a very educable creature, as Professor Yerkes has shown. In a careful way he confronted his mouse-pupil with alternative pathways marked by different degrees of illumination, or by different colours. If the mouse chose compartment A, it found a clear passage direct to its nest; if it chose compartment B, it was punished by a mild electric shock and it had to take a roundabout road home. Needless to say, the A compartment was sometimes to the right hand, sometimes to the left, else mere position would have been a guide. The experiments showed that the dancing mice learn to discriminate the right path from the wrong, and similar results have been got from other mammals, such as rats and squirrels. There is no proof of learning by ideas, but there is proof of learning by experience. And the same must be true in wild life.

Many mammals, such as cats and rats, learn how to manipulate puzzle-boxes and how to get at the treasure at the heart of a Hampton Court maze. Some of the puzzle-boxes, with a reward of food inside, are quite difficult, for the various bolts and bars have to be dealt with in a particular order, and yet many mammals master the problem. What is plain is that they

gradually eliminate useless movements, that they make fewer and fewer mistakes, that they eventually succeed, and that they register the solution within themselves so that it remains with them for a time. It looks a little like the behaviour of a man who learns a game of skill without thinking. It is a learning by experience, not by ideas or reflection. Thus it is very difficult to suppose that a rat or a cat could form any idea or even picture of the Hampton Court maze—which they nevertheless master.

Learning Tricks.

Given sufficient inducement many of the cleverer mammals will learn to do very sensible things, and no one is wise enough to say that they never understand what they are doing. Yet it is certain that trained animals often exhibit pieces of behaviour which are not nearly so clever as they look. The elephant at the Belle Vue Gardens in Manchester used to collect pennies from benevolent visitors. When it got a penny in its trunk it put it in the slot of an automatic machine which delivered up a biscuit. When a visitor gave the elephant a halfpenny it used to throw it back with disgust. At first sight this seemed almost wise, and there was no doubt some intelligent appreciation of the situation. But it was largely a matter of habituation, the outcome of careful and prolonged training. The elephant was laboriously taught to put the penny in the slot and to discriminate between the useful pennies and the useless halfpennies. It was not nearly so clever as it looked.

Using their Wits.

In the beautiful Zoological Park in Edinburgh the Polar Bear was wont to sit on a rocky peninsula of a water-filled quarry. The visitors threw in buns, some of which floated on the surface. It was often easy for the Polar Bear to collect half a dozen by plunging into the pool. But it had discovered a more interesting way. At the edge of the peninsula it scooped the water gently with its huge paw and made a current which brought the buns ashore. This was a simple piece of behaviour, but it has the smack of intelligence—of putting two and two together in a novel way. It suggests the power of making what is called a "perceptual inference."

On the occasion of a great flood in a meadow it was observed that a number of mares brought

Photo: W. S. Berridge.

THE POLAR BEAR OF THE FAR NORTH.

An animal of extraordinary strength, able with a stroke of its paw to lift a big seal right out of the water and send it crashing along the ice. The food consists chiefly of seals. The sexes wander separately. A hole is often dug as a winter retreat, but there is no hibernation. A polar bear in captivity has been seen making a current with its paw in the water of its pool in order to secure floating buns without trouble—an instance of clever intelligence.

their foals to the top of a knoll, and stood round about them protecting them against the rising water. A dog has been known to show what was at any rate a plastic appreciation of a varying situation in swimming across a tidal river. It changed its starting-point, they say, according to the flow or ebb of the tide. Arctic foxes and some other wild mammals show great cleverness in dealing with traps, and the manipulative intelligence of elephants is worthy of all our admiration.

From the Smithsonian Report, 1914.

AN ALLIGATOR "YAWNING" IN EXPECTATION OF FOOD.
Note the large number of sharp conical teeth fixed in sockets along the jaws.

§ 7

Why is there not more Intelligence?

When we allow for dexterity and power of association, when we recognise a certain amount of instinctive capacity and a capacity for profiting by experience in an intelligent way, we must admit a certain degree of disappointment when we take a survey of the behaviour of mammals, especially of those with very fine brains, from which we should naturally expect great things. Why is there not more frequent exhibition of intelligence in the stricter sense?

The answer is that most mammals have become in the course of time very well adapted to the ordinary conditions of their life, and tend to leave well alone. They have got their repertory of efficient answers to the ordinary questions of everyday life, and why should they experiment? In the course of the struggle for existence what has been established is efficiency in normal circumstances, and therefore even the higher animals tend to be no cleverer than is necessary. So while many mammals are extraordinarily efficient, they tend to be a little dull. Their mental equipment is adequate for the everyday conditions of their life, but it is not on sufficiently generous lines to admit of, let us say, an interest in Nature or adventurous experiment. Mammals always tend to "play for safety."

We hasten, however, to insert here some very interesting saving clauses.

Experimentation in Play.

A glimpse of what mammals are capable of, were it necessary, may be obtained by watching those that are playful, such as lambs and kids, foals and calves, young foxes and others. For these young creatures let themselves go irresponsibly, they are still unstereotyped, they test what they and their fellows can do. The experimental character of much of animal play is very marked.

It is now recognised by biologists that play among animals is the young form of work, and that the playing period, often so conspicuous, is vitally important as an apprenticeship to the serious business of life and as an opportunity for learning the alphabet of Nature. But the playing period is much more; it is one of the few opportunities animals have of making experiments without too serious responsibilities. Play is Nature's device for allowing elbow-room for new departures (behaviour-variations) which may form part of the raw materials of progress. Play, we repeat, gives us a glimpse of the possibilities of the mammal mind.

A squirrel is just as clever as it needs to be and no more; and of some vanishing mammals, like the beaver, not even this can be said. Humdrum non-plastic efficiency is apt to mean stagnation. Now we have just seen that in the play of young mammals there is an indication of unexhausted possibilities, and we get the same impression when we think of three other facts. (*a*) In those mammals, like dog and horse, which have entered into active co-operative relations with man, we see that the mind of the mammal is capable of much more than the average would lead us to think. When man's sheltering is too complete and the domesticated creature is passive in his grip, the intelligence deteriorates. (*b*) When we study mammals, like the otter, which live a versatile life in a very complex and difficult environment, we get an inspiriting picture of the play of wits. (*c*) Thirdly, when we pass to monkeys, where the fore-limb has become a free hand, where the brain shows a relatively great improvement, where "words" are much used, we cannot fail to recognise the emergence of something new—a restless inquisitiveness, a desire to investigate the world, an unsatisfied tendency to experiment. We are approaching the Dawn of Reason.

Other Glimpses of Intelligence.

THE MIND OF MONKEYS

§ 8

There is a long gamut between the bushy-tailed, almost squirrel-like marmosets and the big-brained chimpanzee. There is great variety of attainment at different levels in the Simian tribe.

To begin at the beginning, it is certain that monkeys have a first-class sensory equipment, especially as regards sight, hearing, and touch. The axes of the two eyes are directed forwards as in man, and a large section of the field of vision is common to both eyes. In other words, monkeys have a more complete stereoscopic vision than the rest of the mammals enjoy. They look more and smell less. They can distinguish different colours, apart from different degrees of brightness in the coloured objects. They are quick to discriminate differences in the shapes of things, e.g. boxes similar in size but different in shape, for if the prize is always put in a box of the same shape they soon learn (by association) to select the profitable one. They learn to discriminate cards with short words or with signs printed on them, coming down when the "Yes" card is shown, remaining on their perch when the card says "No." Bred to a forest life where alertness is a life-or-death quality, they are quick to respond to a sudden movement or to pick out some new feature in their surroundings. And what is true of vision holds also for hearing.

Keen Senses.

Another quality which separates monkeys very markedly from ordinary mammals is their manipulative expertness, the co-ordination of hand and eye. This great gift follows from the fact

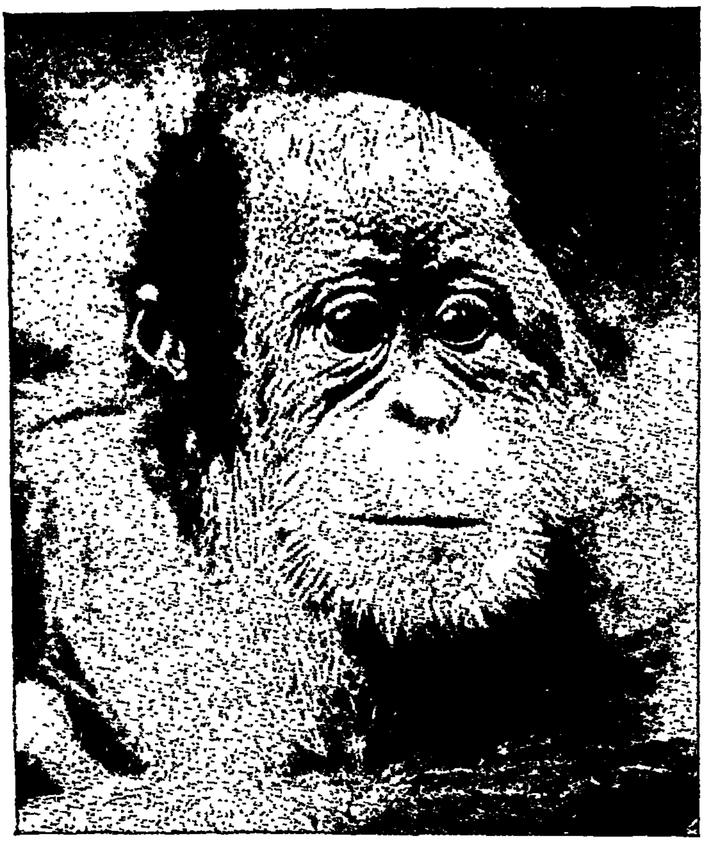


Photo: W. P. Dando.

BABY ORANG.

Notice the small ears and the suggestion of good temper. The mother orang will throw prickly fruits and pieces of branches at those who intrude on her maternal care.

that among monkeys the fore-leg has been emancipated. It has ceased to be indispensable as an organ of support; it has become a climbing, grasping, lifting, handling organ. The fore-limb has become a free hand, and everyone who knows monkeys at all is aware of the zest with which they use their tool. They enjoy pulling things to pieces—a kind of dissection—or screwing the handle off a brush and screwing it on again.

Power of Manipulation.

Professor Thorndike hits the nail on the head when he lays stress on the intensity of activity in monkeys—activity both of body and mind. They are pent-up reservoirs of energy, which almost any influence will tap. Watch a cat or a dog, Professor Thorndike says; it does comparatively few things and is content for long periods to do nothing. It will be splendidly active in response to some stimulus such as food or a friend or a fight, but if nothing appeals to its special make-up, which is very utilitarian in its interests, it will do nothing. "Watch a monkey and you cannot enumerate the things he does, cannot discover the stimuli to which he reacts, cannot conceive the *raison d'être* of his pursuits. Everything appeals to him. He likes to be active for the sake of activity."

Activity for Activity's Sake.

Photo: Gambier Bolton.

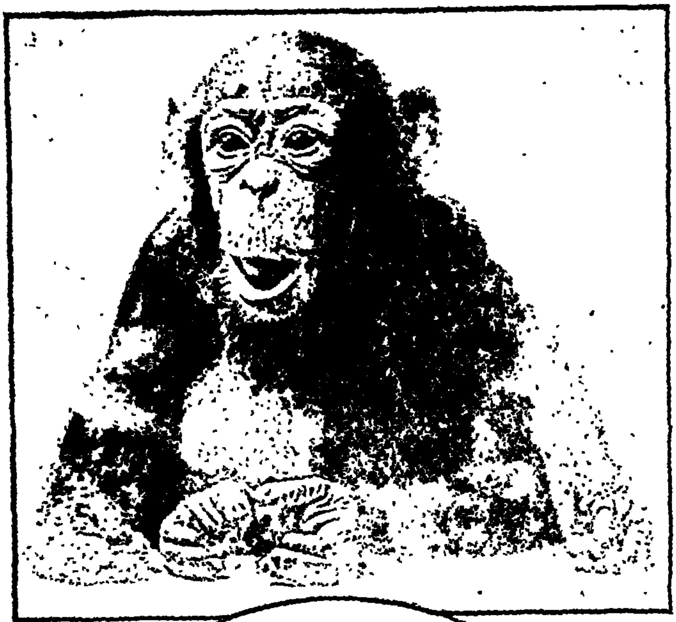
ORANG-UTAN.

A large and heavy ape, frequenting forests in Sumatra and Borneo, living mainly in trees, where a temporary nest is made. The expression is melancholy, the belly very protuberant, the colour yellow-brown, the movements are cautious and slow.

This applies to mental activity as well, and the quality is one of extraordinary interest, for it shows the experimenting mood at a higher turn of the spiral than in any other creature, save man. It points forward to the scientific spirit. We cannot, indeed, believe in the sudden beginning of any quality, and we recall the experimenting of playing mammals, such as kids and kittens, or of inquisitive adults like Kipling's mongoose, Riki-Tiki-Tavi, which made it his business in life to find out about things. But in monkeys the habit of restless experimenting rises to a higher pitch. They appear to be curious about the world. The psychologist whom we have quoted tells of a monkey which happened to hit a projecting wire so as to make it vibrate. He went on repeating the performance hundreds of times during the next few days. Of course, he got nothing out of it, save fun, but it was grist to his mental mill. "The fact of mental life is to monkeys its own reward." The monkey's brain is "tender all over, functioning throughout, set off in action by anything and everything."

Correlated with the quality of restless inquisitiveness and delight in activity for its own sake there is the quality of quickness. We mean not merely the locomotor agility that marks most monkeys, but quickness of perception and plan. It is the sort of quality that life among the branches will engender, where it is so often a case of neck or nothing. It is the quality which we describe as being on the spot, though the phrase has slipped from its original moorings. Speaking of his Bonnet Monkey, an Indian macaque, second cousin to the kind that lives on the Rock of Gibraltar, Professor S. J. Holmes writes: "For keenness of perception, rapidity of action, facility in forming good practical judgments about ways and means of escaping pursuit and of attaining various other ends, Lizzie had few rivals in the animal world. . . . Her perceptions and decisions were so much more rapid than my own that she would frequently transfer her attention, decide upon a line of action, and carry it into effect before I was aware of what she was about. Until I came to guard against her

Sheer Quickness.



1. CHIMPANZEE.
2. BABY ORANG-UTAN.
3. ORANG-UTAN.
4. BABY CHIMPANZEES.

Photos: James's Press Agency.

In his famous book on *The Expression of the Emotions in Man and Animals* (1872) Charles Darwin showed that many forms of facial expression familiar in man have their counterparts in apes and other mammals. He also showed how important the movements of expression are as means of communication between mother and offspring, mate and mate, kith and kin.

The anthropoid apes show notable differences of temperament, as the photographs show. The chimpanzee is lively, cheerful, and educable. The orang is also mild of temper, but often and naturally appears melancholy in captivity. This is not suggested, however, by our photograph of the adult. Both chimpanzee and orang are markedly contrasted with the fierce and gloomy gorilla.

nimble and unexpected manœuvres, she succeeded in getting possession of many apples and peanuts which I had not intended to give her except upon the successful performance of some task."

Quite fundamental to any understanding of animal behaviour is the distinction so clearly drawn by Sir Ray Lankester between the "little-brain" type, rich in inborn or instinctive capacities, but relatively slow to learn, and the "big-brain" type, with a relatively poor endowment of specialised instincts, but with great educability. The "little-brain" type finds its climax in ants and bees; the "big-brain" type in horses and dogs, elephants and monkeys. And of all animals monkeys are the quickest to learn, if we use the word "learn" to mean the formation of useful associations between this and that, between a given sense-presentation and a particular piece of behaviour.

Quick to Learn.

Photo: W. P. Dando.

CHIMPANZEE.

An African ape, at home in the equatorial forests, a lively and playful creature, eminently educable.

Some of us remember Sally, the chimpanzee at the "Zoo" with which Dr. Romanes used to experiment. She was taught to give her teacher the number of straws he asked for, and she soon learned to do so up to five. If she handed a number not asked for, her offer was refused; if she gave the proper number, she got a piece of fruit. If she was asked for five straws, she picked them up individually and placed them in her mouth, and when she had gathered five she presented them together in her hand. Attempts to teach her to give six to ten straws were not very successful. For Sally "above six" meant "many," and besides, her limits of patience were probably less than her range of computation. This was hinted at by the highly interesting circumstance that when dealing with numbers above five she very frequently doubled over a straw so as to make it present two ends and thus appear as two straws. The doubling of the straw looked like an intelligent device to save time, and it was persistently resorted to in spite of the fact that her teacher always refused to accept a doubled straw as equivalent to two straws. Here we get a glimpse of something beyond the mere association of a sound—"Five"—and that number of straws.

The Case of Sally.

The front of the cage in which Professor Holmes kept Lizzie was made of vertical bars which allowed her to reach out with her arm. On a board with an upright nail as handle there was placed an apple—out of Lizzie's reach. She reached immediately for the nail, pulled the board in and got the apple. "There was no employment of the method of trial and error; there was direct appropriate action following the perception of her relation to board, nail, and

The Case of Lizzie.

apple." Of course her ancestors may have been adepts at drawing a fruit-laden branch within their reach, but the simple experiment was very instructive. All the more instructive because in many other cases the experiments indicate a gradual sifting out of useless movements and an eventual retention of the one that pays. When Lizzie was given a vaseline bottle containing a peanut and closed with a cork, she at once pulled the cork out with her teeth, obeying the instinct to bite at new objects, but she never learned to turn the bottle upside down and let the nut drop out. She often got the nut, and after some education she got it more quickly than she did at first, but there was no indication that she ever perceived the fit and proper way of getting what she wanted. "In the course of her intent efforts her mind seemed so absorbed with the object of desire that it was never focussed on the means of attaining that object. There was no deliberation, and no discrimination between the important and the unimportant elements in her behaviour. The gradually increasing facility of her performances depended on the apparently unconscious elimination of useless movements." This may be called learning, but it is learning at a very low level; it is far from learning by ideas; it is hardly even learning by experiment; it is not more than learning by experience, it is not more than fumbling at learning!

Trial and Error.

A higher note is struck in the behaviour of some more highly endowed monkeys. In many experiments, chiefly in the way of getting into boxes difficult to open, there is evidence (1) of attentive persistent experiment, (2) of the rapid elimination of ineffective movements, and (3) of remembering the solution when it was discovered. Kinnaman taught two macaques the Hampton Court Maze, a feat which probably means a memory of movements, and we get an interesting glimpse in his observation that they began to smack their lips audibly when they reached the latter part of their course, and began to feel, dare one say, "We are right this time."

In getting into "puzzle-boxes" and into "combination-boxes" (where the barriers must be overcome in a definite order), monkeys learn by the trial and error method much more quickly than cats and dogs do, and a very suggestive fact emphasised by Professor Thorndike is "a process of sudden acquisition by a rapid, often apparently instantaneous abandonment of the unsuccessful movements and selection of the appropriate one, which rivals in suddenness the selections made by human beings in similar performances." A higher note still was sounded by one of Thorndike's monkeys which opened a puzzle-box at once, eight months after his previous experience with it. For here was some sort of registration of a solution.

Imitation.

Two chimpanzees in the Dublin Zoo were often to be seen washing the two shelves of their cupboard and "wringing" the wet cloth in the approved fashion. It was like a caricature of a washerwoman, and someone said, "What mimics they are!" Now we do not know whether that was or was not the case with the chimpanzees, but the majority of the experiments that have been made do not lead us to attach to imitation so much importance as is usually given to it by the popular interpreter. There are instances where a monkey that had given up a puzzle in despair returned to it when it had seen its neighbour succeed, but most of the experiments suggest that the creature has to find out for itself. Even with such a simple problem as drawing food near with a stick, it often seems of little use to show the monkey how it is done. Placing a bit of food outside his monkey's cage, Professor Holmes "poked it about with the stick so as to give her a suggestion of how the stick might be employed to move the food within reach, but although the act was repeated many times Lizzie never showed the least inclination to use the stick to her advantage." Perhaps the idea of a "tool" is beyond the Bonnet Monkey, yet here again we must be cautious, for Professor L. T. Hobhouse had a monkey of the same macaque genus which learned in the course of time to use a crooked stick with great effect.

The Case of Peter.

Perhaps the cleverest monkey as yet studied was a performing chimpanzee called Peter, which has been generously described by Dr. Lightner Wilmer. Peter could skate and cycle, thread needles and untie knots, smoke a cigarette and string beads, screw in nails and unlock locks. But what Peter was thinking about all the time it was hard to guess, and there is very little evidence

Photo: C. Reid.

COMMON OTTER.

One of the most resourceful of animals and the "most playsomest crittur on God's earth." It neither stores nor hibernates, but survives in virtue of its wits and because of the careful education of the young. The otter is a roving animal, often with more than one resting-place; it has been known to travel fifteen miles in a night.

to suggest that his rapid power of putting two and two together ever rose above a sort of concrete mental experimenting, which Dr. Romanes used to call perceptual inference. Without supposing that there are hard-and-fast boundary lines, we cannot avoid the general conclusion that, while monkeys are often intelligent, they seldom, if ever, show even hints of reason, i.e. of working or playing with general ideas. That remains Man's prerogative.

The Bustle of the Mind.

In mammals like otters, foxes, stoats, hares, and elephants, what a complex of tides and currents there must be in the brain-mind! We may think of a stream with currents at different levels. Lowest there are the *basal appetites* of hunger and sex, often with eddies rising to the surface. Then there are the *primary emotions*, such as fear of hereditary enemies and maternal affection for offspring. Above these are *instinctive aptitudes*, inborn powers of doing clever things without having to learn how. But in mammals these are often expressed along with, or as it were through, the controlled life of *intelligent activity*, where there is more clear-cut perceptual influence.

Higher still are the records or memories of individual experience and the registration of individual habits, while on the surface is the instreaming multitude of messages from the outside world, like raindrops and hailstones on the stream, some of them penetrating deeply, being, as we say, full of meaning. The mind of the higher animal is in some respects like a child's mind, in having little in the way of clear-cut ideas, in showing no reason in the strict sense, and in its extraordinary educability, but it differs from the child's mind entirely in the sure effectiveness of a certain repertory of responses. It is efficient to a degree.

"Until at last arose the Man."

Man's brain is more complicated than that of the higher apes—gorilla, orang, and chimpanzee—and it is relatively larger. But the improvements in structure do not seem in themselves sufficient to account for man's great advance in intelligence.

The rill of inner life has become a swift stream, sometimes a rushing torrent. Besides perceptual inference or *Intelligence*—a sort of picture-logic, which some animals likewise have—there is conceptual inference—or *Reason*—an internal experimenting with general ideas. Even the cleverest animals, it would seem, do not get much beyond playing with "particulars"; man plays an internal game of chess with "universals." Intelligent behaviour may go a long way with mental images; rational conduct demands general ideas. It may be, however, that "percepts" and "concepts" differ rather in degree than in kind, and that the passage from one to the other meant a higher power of forming associations. A clever dog has probably a generalised percept of man, as distinguished from a memory-image of the particular men it has known, but man alone has the concept Man, or Mankind, or Humanity. Experimenting with concepts or general ideas is what we call Reason.

Here, of course, we get into deep waters, and perhaps it is wisest not to attempt too much. So we shall content ourselves here with pointing out that Man's advance in intelligence and from intelligence to reason is closely wrapped up with his power of speech. What animals began—a small vocabulary—he has carried to high perfection. But what is distinctive is not the vocabulary so much as the habit of making sentences, of expressing judgments in a way which admitted of communication between mind and mind. The multiplication of words meant much, the use of words as symbols of general ideas meant even more, for it meant the possibility of playing the internal game of thinking; but perhaps the most important advance of all was the means of comparing notes with neighbours, of corroborating individual experience by social intercourse. With words, also, it became easier to enregister outside himself the gains of the past. It is not without significance that the Greek Logos, which may be translated "the word," may also be translated Mind.

Photo: W. S. Berridge.

YOUNG CHEETAHS, OR HUNTING LEOPARDS.

Trained to hunt from time immemorial and quite easily tamed. Cheetahs occur in India, Persia, Turkestan, and Africa.

§ 9

Looking Backwards.

When we take a survey of animal behaviour we see a long inclined plane. The outer world provokes simple creatures to answer back; simple creatures act experimentally on their surroundings. From the beginning this twofold process has been going on, receiving stimuli from the environment and acting upon the environment, and according to the efficiency of the reactions and actions living creatures have been sifted for millions of years. One main line of advance has been opening new gateways of knowledge—the senses, which are far more than five in number. The other main line of advance has been in most general terms, experimenting or testing, probing and proving, trying one key after another till a door is unlocked. There is progress in multiplying the gateways of knowledge and making them more discriminating, and there is progress in making the modes of experimenting more wide-awake, more controlled, and more resolute. But behind both of these is

the characteristically vital power of enregistering within the organism the lessons of the past. In the life of the individual these enregistrations are illustrated by memories and habituations and habits; in the life of the race they are illustrated by reflex actions and instinctive capacities.

We must not shirk the very difficult question of the relation between the bodily and the mental side of behaviour.

Body and Mind.

(*a*) Some great thinkers have taught that the mind is a reality by itself which plays upon the instrument of the brain and body. As the instrument gets worn and dusty the playing is not so good as it once was, but the player is still himself. This theory of the essential independence of the mind is a very beautiful one, but those who like it when applied to themselves are not always so fond of it when it is applied to other intelligent creatures like rooks and elephants. It may be, however, that there is a gradual emancipation of the mind which has gone furthest in Man and is still progressing.

(*b*) Some other thinkers have taught that the inner life of thought and feeling is only, as it were, an echo of the really important activity—that of the body and brain. Ideas are just foam-bells on the hurrying streams and circling eddies of matter and energy that make up our physiological life. To most of us this theory is impossible, because we are quite sure that ideas and feelings and purposes, which cannot be translated into matter and motion, are the clearest realities in our experience, and that they count for good and ill all through our life. They are more than the tickings of the clock; they make the wheels go round.

(*c*) There are others who think that the most scientific position is simply to recognise both the bodily and the mental activities as equally important, and so closely interwoven that they cannot be separated. Perhaps they are just the outer and the inner aspects of one reality—the life of the creature. Perhaps they are like the concave and convex curves of a dome, like the two sides of a shield. Perhaps the life of the organism is always a unity, at one time appearing more conspicuously as Mind-body, at another time as Body-mind. The most important fact is that neither aspect can be left out. By no jugglery with words can we get Mind out of Matter and Motion. And since we are in ourselves quite sure of our Mind, we are probably safe in saying that in the beginning was Mind. This is in accordance with Aristotle's saying that there is nothing in the end which was not also in kind present in the beginning—whatever we mean by beginning.

In conclusion.

What has led to the truly wonderful result which we admire in a creature like a dog or an otter, a horse or a hare? In general, we may say, just two main processes—(1) testing all things, and (2) holding fast that which is good. New departures occur and these are tested for what they are worth. Idiosyncrasies crop up and they are sifted. New cards come mysteriously from within into the creature's hand, and they are played—for better or for worse. So by new variations and their sifting, by experimenting and enregistering the results, the mind has gradually evolved and will continue to evolve.

Reproduced from "The Forces of Nature" (Messrs. Macmillan).

THE AURORA BOREALIS

The aurora borealis is one of the most beautiful spectacles in the sky. The colours and shape change every instant; sometimes a fan-like cluster of rays, at other times long golden draperies gliding one over the other. Blue, green, yellow, red, and white combine to give a glorious display of colour. The theory of its origin is still, in part, obscure, but there can be no doubt that the aurora is related to the magnetic phenomena of the earth and therefore is connected with the electrical influence of the sun.

VIII

FOUNDATIONS OF THE UNIVERSE

THE WORLD OF ATOMS

MOST people have heard of the oriental race which puzzled over the foundations of the universe, and decided that it must be supported on the back of a giant elephant. But the elephant? They put it on the back of a monstrous tortoise, and there they let the matter end. If every animal in nature had been called upon, they would have been no nearer a foundation. Most ancient peoples, indeed, made no effort to find a foundation. The universe was a very compact little structure, mainly composed of the earth and the great canopy over the earth which they called the sky. They left it, as a whole, floating in nothing. And in this the ancients were wiser than they knew. Things do not fall down unless they are pulled down by that mysterious force which we call gravitation. The earth, it is true, is pulled by the sun, and would fall into it; but the earth escapes this fiery fate by circulating at great speed round the sun. The stars pull each other; but it has already been explained that they meet this by travelling rapidly in gigantic orbits. Yet we do, in a new sense of the word, need foundations of the universe. Our mind craves for some explanation of the matter out of which the universe is made. For this explanation we turn to modern Physics and Chemistry. Both these sciences study, under different aspects, matter and energy; and between them they have put together a conception of the fundamental nature of things which marks an epoch in the history of human thought.

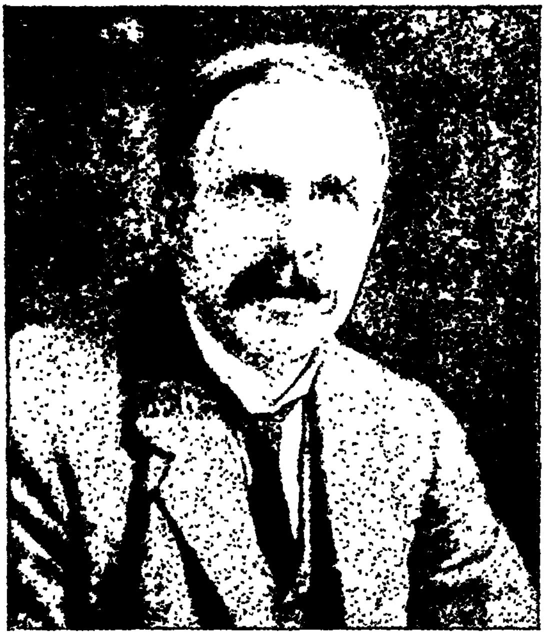


Photo: Elliott & Fry.

SIR ERNEST RUTHERFORD.

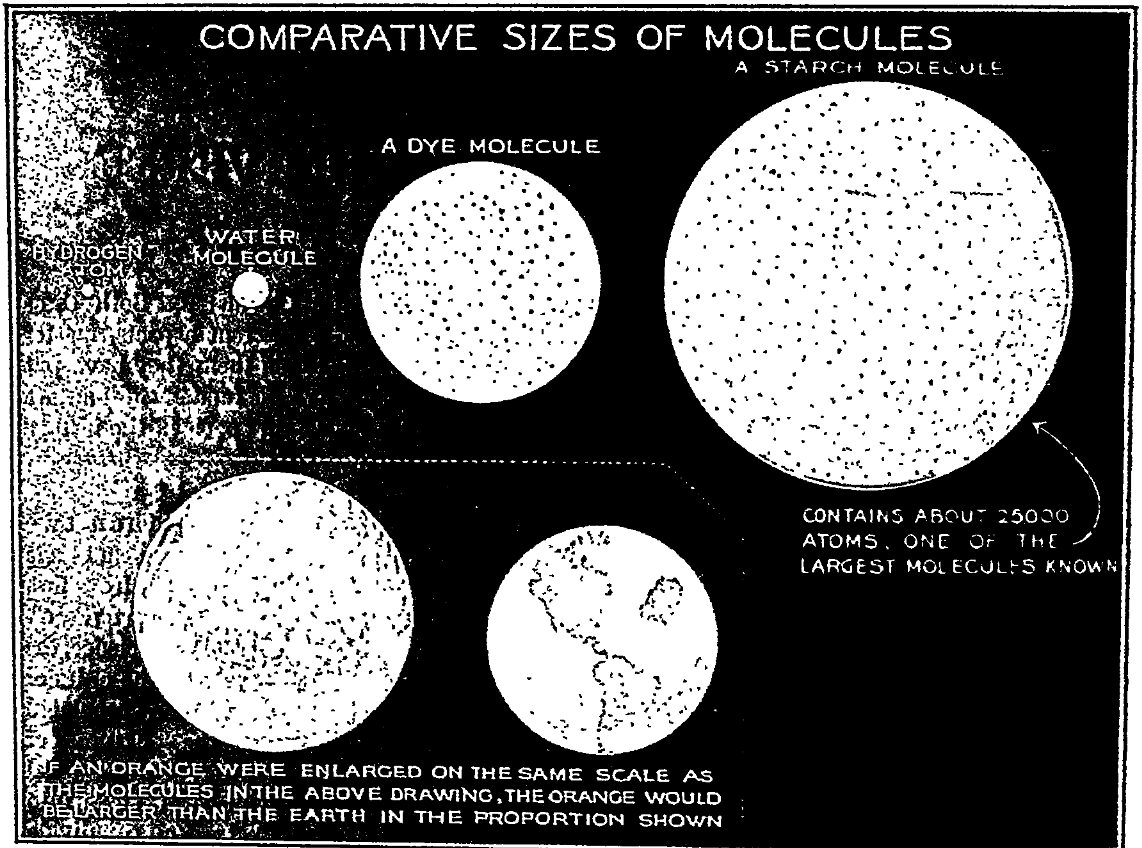
One of our most eminent physicists, who has succeeded Sir J. J. Thomson as Cavendish Professor of Physics at the University of Cambridge. The modern theory of the structure of the atom is largely due to him.

§ 1

The Bricks of the Cosmos.

More than two thousand years ago the first men of science, the Greeks of the cities of Asia Minor, speculated on the nature of matter. You can grind a piece of stone into dust. You can divide a spoonful of water into as many drops as you like. Apparently you can go on dividing as long as you have got apparatus fine enough for the work. But there must be a limit, these Greeks said, and so they supposed that all matter was ultimately composed of minute particles which were indivisible. That is the meaning of the Greek word "atom."

Like so many other ideas of these brilliant early Greek thinkers, the atom was a sound conception. We know to-day that matter is composed of atoms. But science was then so young that the way in which the Greeks applied the idea was not very profound. A liquid or a gas, they said, consisted of round, smooth atoms, which would not cling together. Then



An atom is the smallest particle of a chemical element. Two or more atoms come together to form a molecule; thus molecules form the mass of matter. A molecule of water is made up of two atoms of hydrogen and one atom of oxygen. Molecules of different substances, therefore, are of different sizes according to the number and kind of the particular atoms of which they are composed. A starch molecule contains no less than 25,000 atoms.

Molecules, of course, are invisible. The above diagram illustrates the *comparative* sizes of molecules.

there were atoms with rough surfaces, " hooky " surfaces, and these stuck together and formed solids. The atoms of iron or marble, for instance, were so very hooky that, once they got together, a strong man could not tear them apart. The Greeks thought that the explanation of the universe was that an infinite number of these atoms had been moving and mixing in an infinite space during an infinite time, and had at last hit by chance on the particular combination which is our universe.

This was too simple and superficial. The idea of atoms was cast aside, only to be advanced again in various ways. It was the famous Manchester chemist, John Dalton, who restored it in the early years of the nineteenth century. He first definitely formulated the atomic theory as a scientific hypothesis. The whole physical and chemical science of that century was now based upon the atom, and it is quite a mistake to suppose that recent discoveries have discredited " atomism." An atom is the smallest particle of a chemical element. No one has ever seen an atom. Even the wonderful new microscope which has just been invented cannot possibly show us particles of matter which are a million times smaller than the breadth of a hair; for that is the size of atoms. We can weigh them and measure them, though they are invisible, and we know that all matter is composed of them. It is a new discovery that atoms are not indivisible. They consist themselves of still smaller particles, as we shall see. But the atoms exist all the same, and we may still say that they are the bricks of which the material universe is built.

But if we had some magical glass by means of which we could see into the structure of material things, we should not see the atoms put evenly together as bricks are in a wall. As a

rule, two or more atoms first come together to form a larger particle, which we call a "molecule." Single atoms do not, as a rule, exist apart from other atoms; if a molecule is broken up, the individual atoms seek to unite with other atoms of another kind or amongst themselves. For example, three atoms of oxygen form what we call ozone; two atoms of hydrogen uniting with one atom of oxygen form water. It is molecules that form the mass of matter; a molecule, as it has been expressed, is a little building of which atoms are the bricks.

In this way we get a useful first view of the material things we handle. In a liquid the molecules of the liquid cling together loosely. They remain together as a body, but they roll over and away from each other. There is "cohesion" between them, but it is less powerful than in a solid. Put some water in a kettle over the lighted gas, and presently the tiny molecules of water will rush through the spout in a cloud of steam and scatter over the kitchen. The heat has broken their bond of association and turned the water into something like a gas; though we know that the particles will come together again, as they cool, and form once more drops of water.

In a gas the molecules have full individual liberty. They are in a state of violent movement, and they form no union with each other. If we want to force them to enter into the loose sort of association which molecules have in a liquid, we have to slow down their individual movements by applying severe cold. That is how a modern man of science liquefies gases. No power that we have will liquefy air at its ordinary temperature. In *very* severe cold, on the other hand, the air will spontaneously become liquid. Some day, when the fires of the sun have sunk very low, the temperature of the earth will be less than $-200°$ C.: that is to say, more than two hundred degrees Centigrade below freezing-point. It will sink to the temperature of the moon. Our atmosphere will then be an ocean of liquid air, 35 feet deep, lying upon the solidly frozen masses of our water-oceans.

In a solid the molecules cling firmly to each other. We need a force equal to twenty-five tons to tear asunder the molecules in a bar of iron an inch thick. Yet the structure is not "solid" in the popular sense of the word. If you put a piece of solid gold in a little pool of mercury, the gold will take in the mercury *between* its molecules, as if it were porous like a sponge. The hardest solid is more like a lattice-work than what we usually mean by "solid"; though the molecules are not fixed, like the bars of a lattice-work, but are in violent motion; they vibrate about equilibrium positions. If we could see right into the heart of a bit of the hardest steel, we should see billions of separate molecules, at some distance from each other, all moving rapidly to and fro.

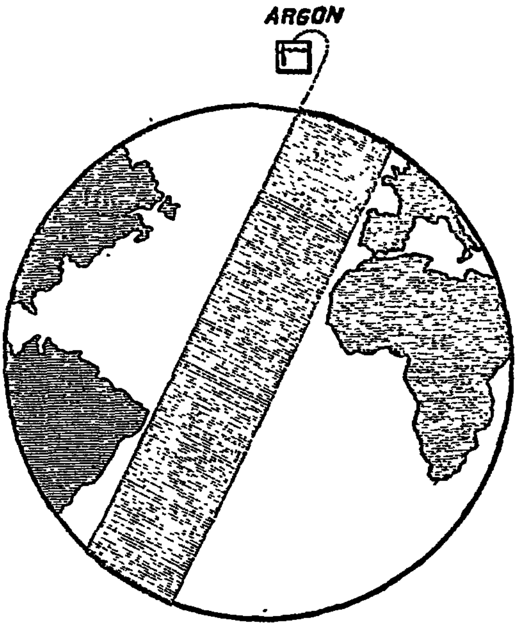
Photo: Rischgitz Collection.

J. CLERK-MAXWELL.

One of the greatest scientific men who have ever lived. He revolutionised physics with his electro-magnetic theory of light, and practically all modern researches have had their origin, direct or indirect, in his work. Together with Faraday he constitutes one of the main scientific glories of the nineteenth century.

This molecular movement can, in a measure, be made visible. It was noticed by a microscopist named Brown that, in a solution containing very fine suspended particles,

the particles were in constant movement. Under a powerful microscope these particles are seen to be violently agitated; they are each independently darting hither and thither somewhat like a lot of billiard balls on a billiard table, colliding and bounding about in all directions. Thousands of times a second these encounters occur, and this lively commotion is always going on, this incessant colliding of one molecule with another is the normal condition of affairs; not one of them is at rest. The reason for this has been worked out, and it is now known



INCONCEIVABLE NUMBERS AND INCONCEIVABLY SMALL PARTICLES.

The molecules, which are inconceivably small, are, on the other hand, so numerous that if one was able to place, end to end, all those which are contained in, for example, a cubic centimetre of gas (less than half a cubic inch), one would obtain a line capable of passing two hundred times round the earth.

that these particles move about because they are being incessantly bombarded by the molecules of the liquid. The molecules cannot, of course, be seen, but the fact of their incessant movement is revealed to the eye by the behaviour of the visible suspended particles. This incessant movement in the world of molecules is called the Brownian movement, and is a striking proof of the reality of molecular motions.

§ 2

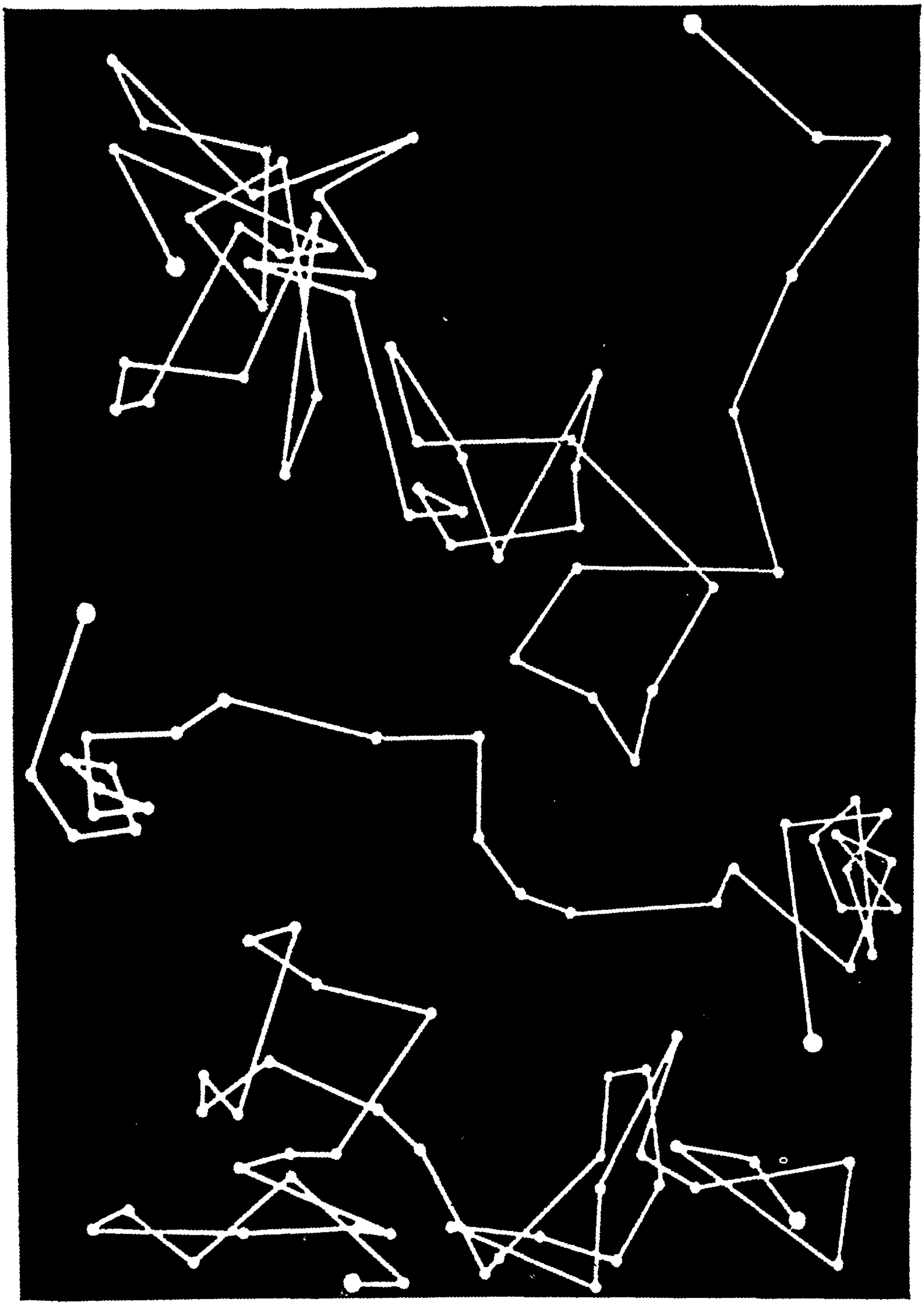
The exploration of this wonder-world of atoms and molecules by the physicists and chemists of to-day is one of the most impressive triumphs of modern science. Quite apart from radium and electrons and other sensational discoveries of recent years, the study of ordinary matter is hardly inferior, either in interest or audacity, to the work of the astronomer. And there is the same foundation in both cases—marvellous apparatus, and trains of mathematical reasoning that would have astonished Euclid or Archimedes. Extraordinary, therefore, as are some of the facts and figures we are now going to give in connection with the minuteness of atoms and molecules, let us bear in mind that we owe them to the most solid and severe processes of human thought.

The Wonder-World of Atoms.

Yet the principle can in most cases be made so clear that the reader will not be asked to take much on trust. It is, for instance, a matter of common knowledge that gold is soft enough to be beaten into gold leaf. It is a matter of common sense, one hopes, that if you beat a measured cube of gold into a leaf six inches square, the mathematician can tell the thickness of that leaf without measuring it. As a matter of fact, a single grain of gold has been beaten into a leaf seventy-five inches square. Now the mathematician can easily find that when a single grain of gold is beaten out to that size, the leaf must be $\frac{1}{367,000}$ of an inch thick, or about a thousand times thinner than the paper on which these words are printed; yet the leaf must be several molecules thick.

The finest gold leaf is, in fact, too thick for our purpose, and we turn with a new interest to that toy of our boyhood, the soap-bubble. If you carefully examine one of these delicate films of soapy water, you notice certain dark spots or patches on them. These are their thinnest parts, and by two quite independent methods—one using electricity and the other light—we have found that at these spots the bubble is less than the three-millionth of an inch thick! But the molecules in the film cling together so firmly that they must be at least twenty or thirty deep in the thinnest part. A molecule, therefore, must be far less than the three-millionth of an inch thick.

We found next that a film of oil on the surface of water may be even thinner than a soap-bubble. Professor Perrin, the great French

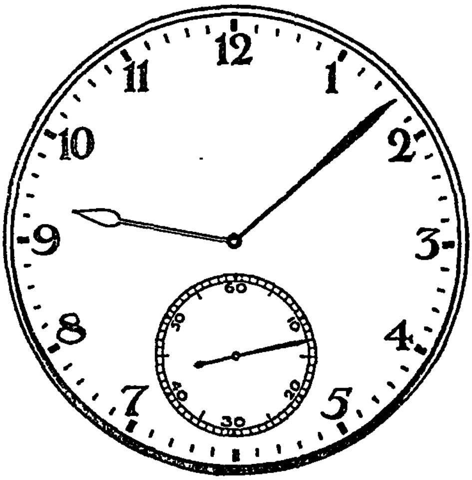


THE BROWNIAN MOVEMENT.

A diagram, constructed from actual observations, showing the erratic paths pursued by very fine particles suspended in a liquid, when bombarded by the molecules of the liquid. This movement is called the Brownian movement, and it furnishes a striking illustration of the truth of the theory that the molecules of a body are in a state of continual motion.

authority on atoms, got films of oil down to the fifty-millionth of an inch in thickness! He poured a measured drop of oil upon water. Then he found the exact limits of the area of the oil-sheet by blowing upon the water a fine powder which spread to the edge of the film and clearly outlined it. The rest is safe and simple calculation, as in the case of the beaten grain of gold. Now this film of oil must have been at least two molecules deep, so a single molecule of oil is considerably less than a hundred-millionth of an inch in diameter.

Innumerable methods have been tried, and



WHAT IS A MILLION?

In dealing with the infinitely small, it is difficult to apprehend the vast figures with which scientists confront us. A million is one thousand thousand. We may realise what this implies if we consider that a clock beating seconds takes approximately 278 hours (i.e. one week four days fourteen hours) to tick one million times. A billion is one million million. To tick a billion the clock would tick for over 31,735 years.

(In France and America a thousand millions is called a billion.)

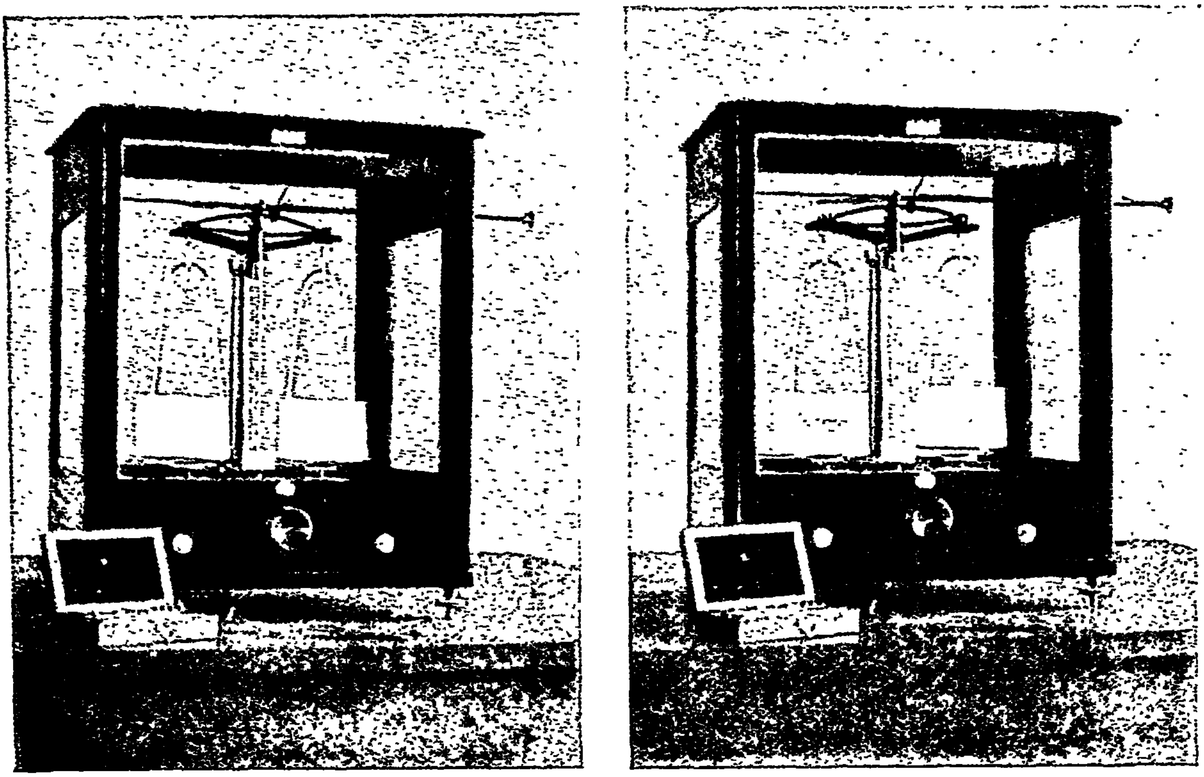
the result is always the same. A single grain of indigo, for instance, will colour a ton of water. This obviously means that the grain contains billions of molecules which spread through the water. A grain of musk will scent a room—pour molecules into every part of it—for several years, yet not lose one-millionth of its mass in a year. There are a hundred ways of showing the minuteness of the ultimate particles of matter, and some of these enable us to give definite figures. On a careful comparison of the best methods we can say that the average molecule of matter is less than the $\frac{1}{125,000,000}$ of an inch in diameter. In a single cubic centimetre of air—a globule about the size of a small marble—there are thirty million billion molecules. And since the molecule is, as we saw, a group or cluster of atoms, the atom itself is smaller. Atoms, for reasons which we shall see later, differ very greatly from each other in size and weight. It is enough to say that some of them are so small that it would take 400,000,000 of them, in a line, to cover an inch of space; and that it takes at least a trillion atoms of gold to weigh a single gramme. Five million atoms of helium could be placed in a line across the diameter of a full stop.

And this is only the beginning of the wonders that were done with "ordinary matter," quite apart from radium and its revelations, to which we will come presently.

The Energy of Atoms.

Most people have heard of "atomic energy," and the extraordinary things that might be accomplished if we could harness this energy and turn it to human use. A deeper and more wonderful source of this energy has been discovered in the last twenty years, but it is well to realise that the atoms themselves have stupendous energy. The atoms of matter are vibrating or gyrating with extraordinary vigour. The piece of cold iron you hold in your hand, the bit of brick you pick up, or the penny you take from your pocket is a colossal reservoir of energy, since it consists of billions of moving atoms. To realise the total energy, of course, we should have to witness a transformation such as we do in atoms of radio-active elements, about which we shall have something to say presently.

If we put a grain of indigo in a glass of water, or a grain of musk in a perfectly still room, we soon realise that molecules travel. Similarly, the fact that gases spread until they fill every "empty" available space shows definitely that they consist of small particles travelling at great speed. The physicist brings his refined methods to bear on these things, and he measures the energy and velocity of these infinitely minute molecules. He tells us that molecules of oxygen, at the temperature of melting ice, travel at the rate of about 500 yards a second—more than a quarter of a mile a second. Molecules of hydrogen travel at four times that speed, or three times the speed with which a bullet leaves a rifle. Each



From "Scientific Ideas of To-day."

DETECTING A SMALL QUANTITY OF MATTER.

In the left-hand photograph the two pieces of paper exactly balance. The balance used is very sensitive, and when the single word "atoms" has been written with a lead pencil upon one of the papers the additional weight is sufficient to depress one of the pans, as shown in the second photograph. The spectroscope will detect less than one-millionth of the matter contained in the word pencilled above.

molecule of the air, which seems so still in the house on a summer's day, is really travelling faster than a rifle bullet does at the beginning of its journey. It collides with another molecule every twenty-thousandth of an inch of its journey. It is turned from its course 5,000,000,000 times in every second by collisions. If we could stop the molecules of hydrogen gas, and utilise their energy, as we utilise the energy of steam or the energy of the water at Niagara, we should find enough in every gramme of gas (about two-thousandths of a pound) to raise a third of a ton to a height of forty inches.

I have used for comparison the speed of a rifle bullet, and in an earlier generation people would have thought it impossible even to estimate this. If is, of course, easy. We put two screens in the path of the bullet, one near the rifle and the other some distance away. We connect them electrically and use a fine time-recording machine, and the bullet itself registers the time it takes to travel from the first to the second screen.

Now this is very simple and superficial work in comparison with the system of exact and minute measurements which the physicist and chemist use. In one of his interesting works Mr. Charles R. Gibson gives a photograph of two exactly equal pieces of paper in the opposite pans of a fine balance. A single word has been written in pencil on one of these papers, and that little scraping of lead has been enough to bring down the scale! The spectroscope will detect a quantity of matter four million times smaller even than this; and the electroscope is a million times still more sensitive than the spectroscope. We have a heat-measuring instrument, the bolometer, which makes the best thermometer seem Early Victorian. It records the millionth of a degree of temperature. It is such instruments, multiplied by the score, which enable us to do the fine work recorded in these pages.

§ 3
THE DISCOVERY OF X-RAYS AND RADIUM

The Discovery of Sir Wm. Crookes.

But these wonders of the atom are only a prelude to the more romantic and far-reaching discoveries of the new physics—the wonders of the electron. Another and the most important phase of our exploration of the material universe opened with the discovery of radium in 1898.

In the discovery of radio-active elements, a new property of matter was discovered. What followed on the discovery of radium and of the X-rays we shall see.

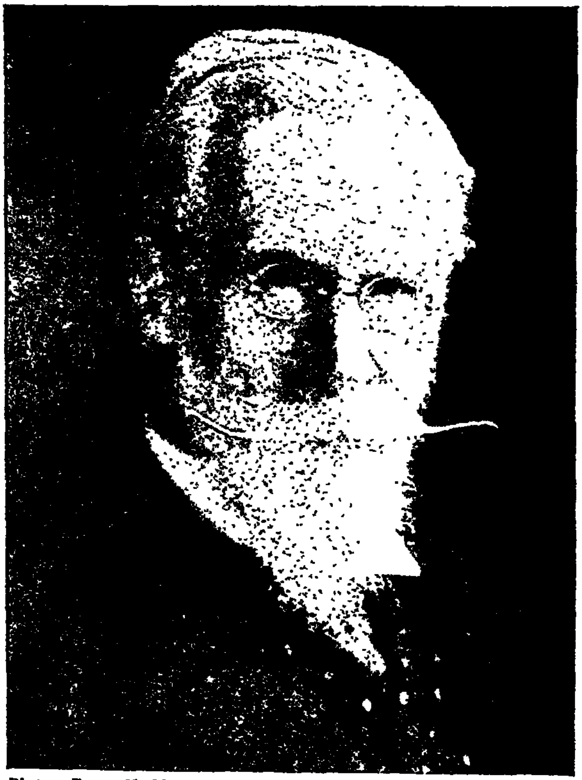


Photo: Ernest H. Mills.

SIR WILLIAM CROOKES.

Sir William Crookes experimented on the electric discharge in vacuum tubes and described the phenomena as a "fourth state of matter." He was actually observing the flight of electrons, but he did not fully appreciate the nature of his experiments.

As Sir Ernest Rutherford, one of our greatest authorities, recently said, the new physics has dissipated the last doubt about the reality of atoms and molecules. The closer examination of matter which we have been able to make shows positively that it is composed of atoms. But we must not take the word now in its original Greek meaning (an "indivisible" thing). The atoms are not indivisible. They can be broken up. They are composed of still smaller particles.

The discovery that the atom was composed of smaller particles was the welcome realisation of a dream that had haunted the imagination of the nineteenth century. Chemists said that there were about eighty different kinds of atoms—different kinds of matter—but no one was satisfied with the multiplicity. Science is always aiming at simplicity and unity. It may be that science has now taken a long step in the direction of explaining the fundamental unity of all matter. The chemist was unable to break up these "elements" into something simpler, so he called their atoms "indivisible" in that sense. But one man of science after another expressed the hope that we would yet discover some fundamental matter of which the various atoms were composed—*one primordial substance from which all the varying forms of matter have been evolved or built up.* Prout suggested this at the very beginning of the century, when atoms were rediscovered by Dalton. Father Secchi, the famous Jesuit astronomer, said that all the atoms were probably evolved from ether; and this was a very favoured speculation. Sir William Crookes talked of "prothyl" as the fundamental substance. Others thought hydrogen was the stuff out of which all the other atoms were composed.

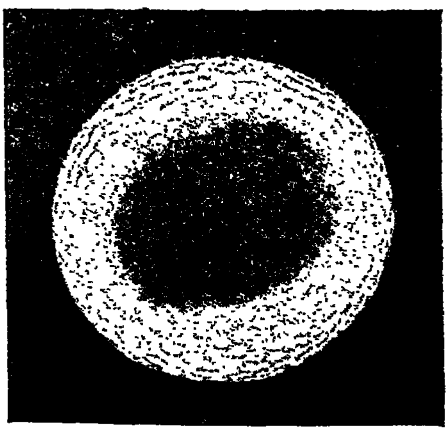


Photo: National Physical Laboratory.

AN X-RAY PHOTOGRAPH OF A GOLF BALL, REVEALING AN IMPERFECT CORE.

The work which finally resulted in the discovery of radium began with some beautiful experiments of

Professor (later Sir William) Crookes in the eighties.

It had been noticed in 1869 that a strange colouring was caused when an electric charge was sent through a vacuum tube—the walls of the glass tube began to glow with a greenish phosphorescence. A vacuum tube is one from which nearly all the air has been pumped, although we can never completely empty the tube. Crookes used such ingenious methods that he reduced the gas in his tubes until it was twenty million times thinner than the atmosphere. He then sent an electric discharge through, and got very remarkable results. The negative pole of the electric current (the "cathode") *gave off rays which faintly lit the molecules of the thin gas in the tube,* and caused a pretty fluorescence on the glass walls of the tube. What were these rays? Crookes at first thought they corresponded to a "new or fourth state of matter." Hitherto we had only been familiar with matter in the three conditions of solid, liquid, and gaseous.

Now Crookes really had the great secret under his eyes. But about twenty years elapsed before the true nature of these rays was finally and independently established by various experiments. The experiments proved "that the rays consisted of a stream of negatively charged particles travelling with enormous velocities from 10,000 to 100,000 miles a second. In addition, it was found that the mass of each particle was exceedingly small, about $\frac{1}{1800}$ of the mass of a hydrogen atom.

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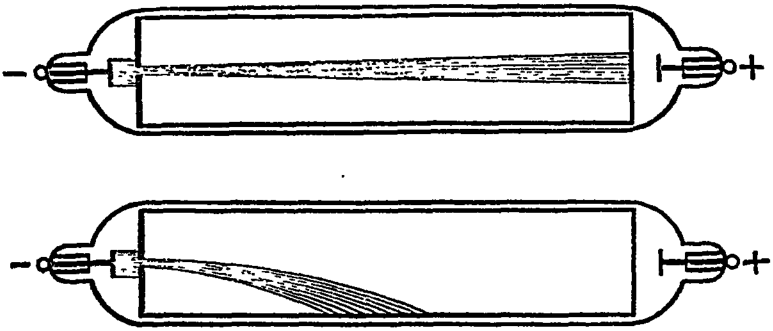
A WONDERFUL X-RAY PHOTOGRAPH

Note the fine details revealed, down to the metal tags of the bootlace and the nails in the heel of the boot.

the lightest atom known to science." *These particles or electrons, as they are now called,*



ELECTRIC DISCHARGE IN A VACUUM TUBE.

The two ends, marked + and —, of a tube from which nearly all air has been exhausted are connected to electric terminals, thus producing an electric discharge in the vacuum tube. This discharge travels straight along the tube, as in the upper diagram. When a magnetic field is applied, however, the rays are deflected, as shown in the lower diagram. The similarity of the behaviour of the electric discharge with the radium rays (see illustration on page 191) shows that the two phenomena may be identified. It was by this means that the characteristics of electrons were first discovered.

were being liberated from the atom. The atoms of matter were breaking down in Crookes tubes. At that time, however, it was premature to think of such a thing, and Crookes preferred to say that the particles of the gas were electrified and hurled against the walls of the tube. He said that it was ordinary matter in a new state—" radiant matter." Another distinguished man of science, Lenard, found that, when he fitted a little plate of aluminium in the glass wall of the tube, the mysterious rays passed through this as if it were a window. They must be waves in the ether, he said.

§ 4

So the story went on from year to year. We shall see in a moment to what it led.

The Discovery of X-rays.

Meanwhile the next great step was when, in 1895, Röntgen discovered the X-rays, which are now known to everybody. He was following up the work of Lenard, and he one day covered a " Crookes tube " with some black stuff. To his astonishment a prepared chemical screen which was near the tube began to glow. *The rays had gone through the black stuff; and on further experiment he found that they would go through stone, living flesh, and all sorts of " opaque " substances.* In a short time the world was astonished to learn that we could photograph the skeleton in a living man's body, locate a penny in the interior of a child that had

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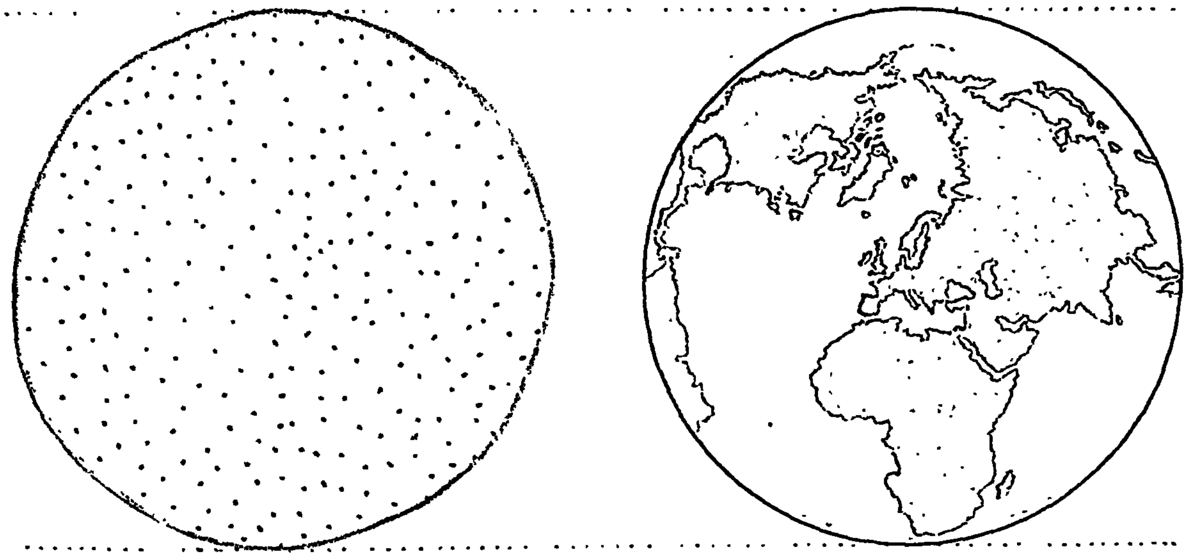
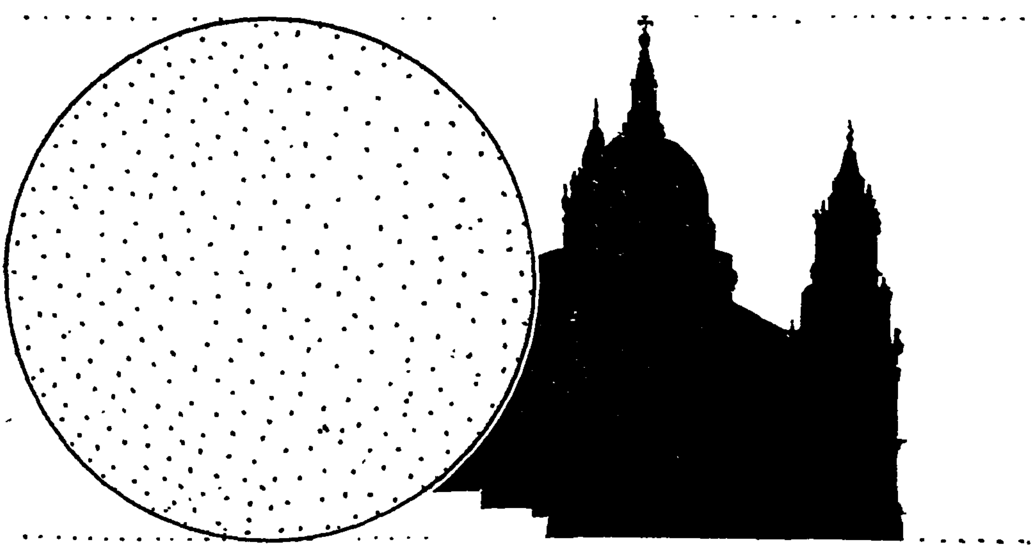
THIS X-RAY PHOTOGRAPH IS THAT OF A HAND OF SOLDIER WOUNDED IN THE GREAT WAR.

Note the pieces of shrapnel which are revealed.



THE RELATIVE SIZES OF ATOMS AND ELECTRONS.

An atom is far too small to be seen. In a bubble of hydrogen gas no larger than the letter "O" there are billions of atoms, whilst an electron is more than a thousand times smaller than the smallest atom. How their size is ascertained is described in the text. In this diagram a bubble of gas is magnified to the size of the world. Adopting this scale, *each atom* in the bubble would then be as large as a tennis ball.



IF AN ATOM WERE MAGNIFIED TO THE SIZE OF ST. PAUL'S CATHEDRAL, EACH ELECTRON IN THE ATOM (AS REPRESENTED BY THE CATHEDRAL) WOULD THEN BE ABOUT THE SIZE OF A SMALL BULLET.

swallowed one, or take an impression of a coin through a slab of stone.

And what are these X-rays? They are not a form of matter; they are not material particles. X-rays were found to be a new variety of *light* with a remarkable power of penetration. We have seen what the spectroscope reveals about the varying nature of light wave-lengths. Light-waves are set up by vibrations in ether,[1] and, as we shall see,

[1] We refer throughout to the "ether" because, although modern theories dispense largely with this conception, the theories of physics are so inextricably interwoven with it that it is necessary, in an elementary exposition, to assume its existence. The modern view will be explained later in the article on Einstein's Theory.

these ether disturbances are all of the same kind; they only differ as regards wave-lengths. The X-rays which Röntgen discovered, then, are light, but a variety of light previously unknown to us; they are ether waves of very short length. X-rays have proved of great value in many directions, as all the world knows, but that we need not discuss at this point. Let us see what followed Röntgen's discovery.

While the world wondered at these marvels, the men of science were eagerly following up the new clue to the mystery of matter which was exercising the mind of Crookes and other investigators. In 1896 Becquerel brought us to the threshold of the great discovery.

Certain substances are phosphorescent—they become luminous after they have been exposed to sunlight for some time, and Becquerel was trying to find if any of these substances give rise to X-rays. One day he chose a salt of the metal uranium. He was going to see if, after exposing it to sunlight, he could photograph a cross with it through an opaque substance. He wrapped it up and laid it aside, to wait for the sun, but he found the uranium salt did not wait for the sun. Some strong radiation from it went through the opaque covering and made an impression of the cross upon the plate underneath. Light or darkness was immaterial. The mysterious rays streamed night and day from the salt. This was something new. Here was a substance which appeared to be producing X-rays; the rays emitted by uranium would penetrate the same opaque substances as the X-rays discovered by Röntgen.

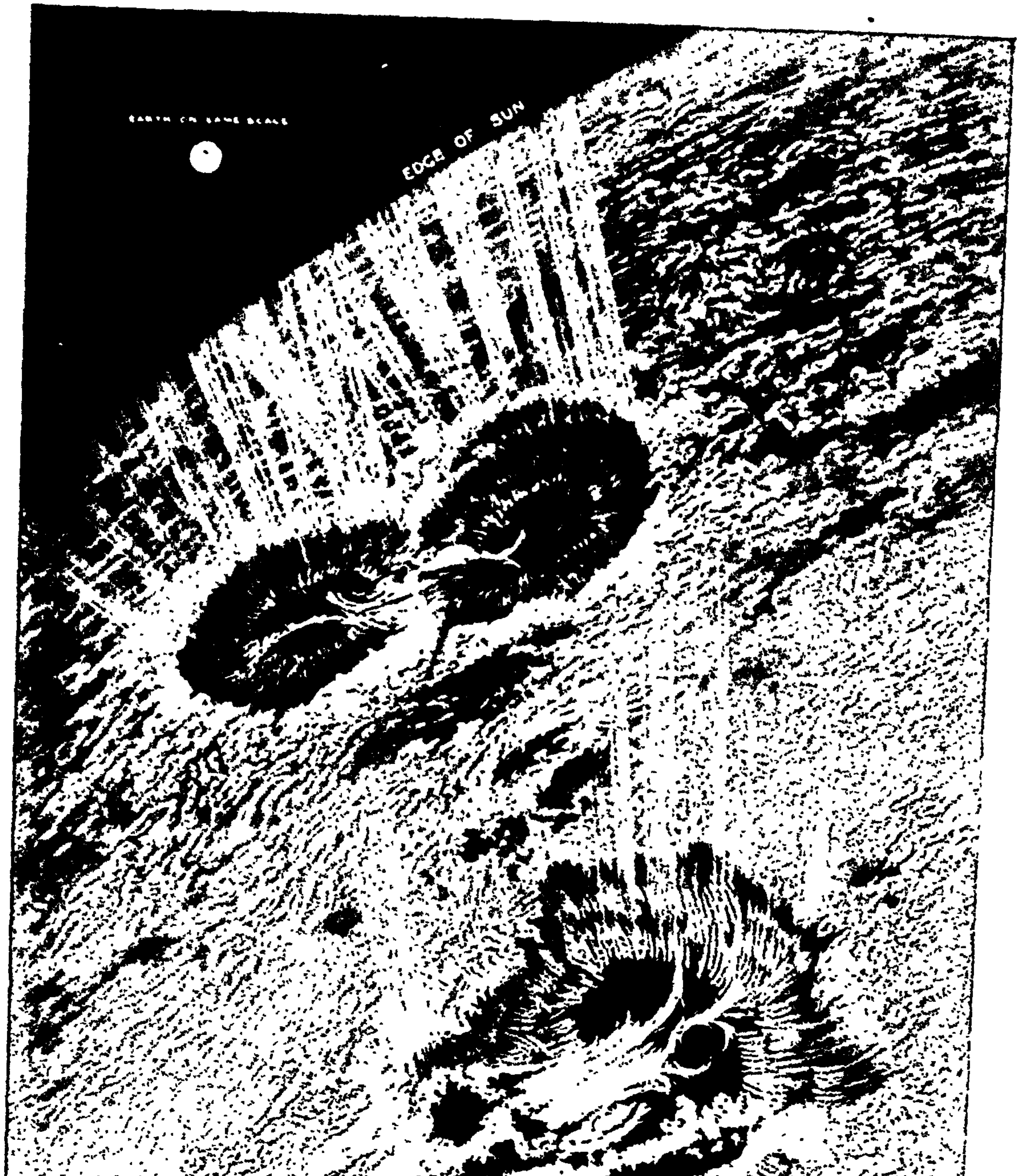
Discovery of Radium.

Now, at the same time as many other investigators, Professor Curie and his Polish wife took up the search. They decided to find out whether the emission came from the uranium itself or *from something associated with it*, and for this purpose they made a chemical analysis of great quantities of minerals. They found a certain kind of pitchblende which was very active, and they analysed tons of it, concentrating always on the radiant element in it. After a time, as they successively worked out the non-radiant matter, the stuff began to glow. In the end they extracted from eight tons of pitchblende about half a teaspoonful of something *that was a million times more radiant than uranium*. There was only one name for it—Radium.

That was the starting-point of the new development of physics and chemistry. From every laboratory in the world came a cry for radium salts (as pure radium was too precious), and hundreds of brilliant workers fastened on the new element. The inquiry was broadened, and, as year followed year, one substance after another was found to possess the power of emitting rays, that is to be radio-active. We know to-day that nearly every form of matter can be stimulated to radio-activity; which, as we shall see, means that *its atoms break up into smaller and wonderfully energetic particles which we call "electrons."* This discovery of electrons has brought about a complete change in our ideas in many directions.

So, instead of atoms being indivisible, they are actually dividing themselves, spontaneously, and giving off throughout the universe tiny fragments of their substance. We shall explain presently what was later discovered about the electron; meanwhile we can say that every glowing metal is pouring out a stream of these electrons. Every arc-lamp is discharging them. Every clap of thunder means a shower of them. Every star is flooding space with them. We are witnessing the spontaneous breaking up of atoms, atoms which had been thought to be indivisible. The sun not only pours out streams of electrons from its own atoms, but the ultra-violet light which it sends to the earth is one of the most powerful agencies for releasing electrons from the surface-atoms of matter on the earth. It is fortunate for us that our atmosphere absorbs most of this ultra-violet or invisible light of the sun—a kind of light which will be explained presently. It has been suggested that, if we received the full flood of it from the sun, our metals would disintegrate under its influence and this "steel civilisation" of ours would be impossible!

But we are here anticipating, we are going beyond radium to the wonderful discoveries which were made by the chemists and physicists of the world who concentrated upon it. The



ELECTRONS STREAMING FROM THE SUN TO THE EARTH.

There are strong reasons for supposing that sun-spots are huge electronic cyclones. The sun is constantly pouring out vast streams of electrons into space. Many of these streams encounter the earth, giving rise to various electrical phenomena.

work of Professor and Mme. Curie was merely the final clue to guide the great search. How it was followed up, how we penetrated into the very heart of the minute atom and discovered new and portentous mines of energy, and how we were able to understand, not only matter, but electricity and light, will be told in the next chapter.

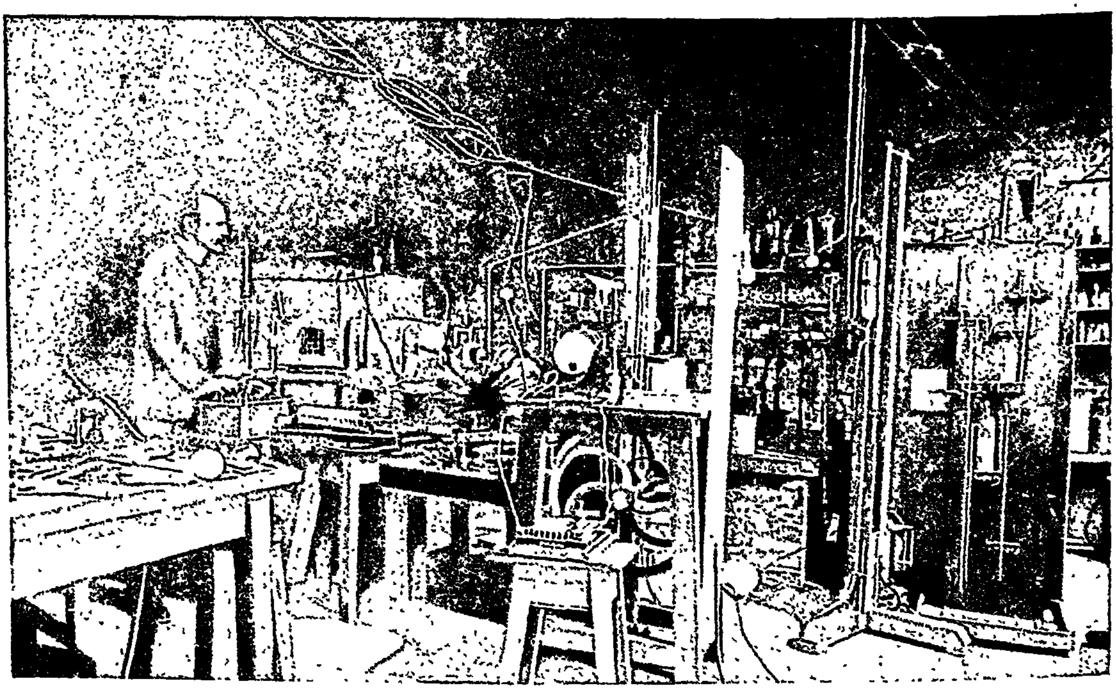
THE DISCOVERY OF THE ELECTRON AND HOW IT EFFECTED A REVOLUTION IN IDEAS

What the discovery of radium implied was only gradually realised. Radium captivated the imagination of the world; it was a boon to medicine, but to the man of science it was at first a most puzzling and most attractive phenomenon. It was felt that some great secret of nature was dimly unveiled in its wonderful manifestations, and there now concentrated upon it as gifted a body of men—conspicuous amongst them Sir J. J. Thomson, Sir Ernest Rutherford, Sir W. Ramsay, and Professor Soddy—as any age could boast, with an apparatus of research as far beyond that of any other age as the *Aquitania* is beyond a Roman galley. Within five years the secret was fairly mastered. Not only were all kinds of matter reduced to a common basis, but the forces of the universe were brought into a unity and understood as they had never been understood before.

§ 5

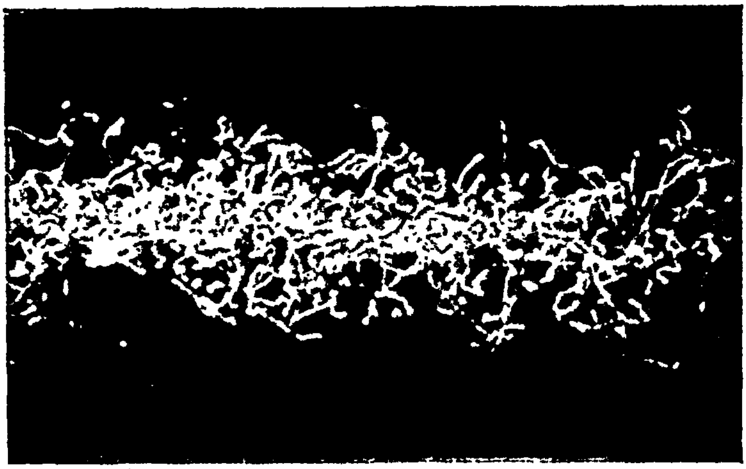
The Discovery of the Electron.

Physicists did not take long to discover that the radiation from radium was very like the radiation in a "Crookes tube." It was quickly recognised, moreover, that both in the tube and in radium



PROFESSOR SIR J. J. THOMSON.

Experimental discoverer of the electronic constitution of matter, in the Cavendish Physical Laboratory, Cambridge. A great investigator, noted for the imaginative range of his hypotheses and his fertility in experimental devices.



From the Smithsonian Report, 1915.

ELECTRONS PRODUCED BY PASSAGE OF X-RAYS THROUGH AIR.

A photograph clearly showing that electrons are definite entities. As electrons leave atoms they may traverse matter or pass through the air in a straight path. The illustration shows the tortuous path of electrons resulting from collision with atoms.

(and other metals) the atoms of matter were somehow breaking down.

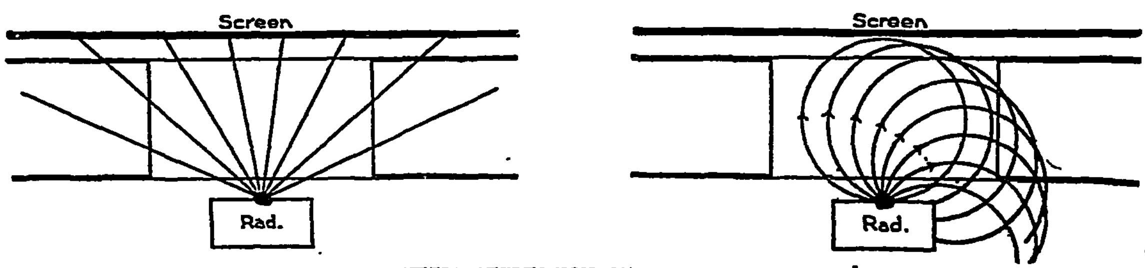
However, the first step was to recognise that there were three distinct and different rays that were given off by such metals as radium and uranium. Sir Ernest Rutherford christened them, after the first three letters of the Greek alphabet, the Alpha, the Beta, and Gamma rays. We are concerned chiefly with the second group and propose here to deal with that group only.[1]

The "Beta rays," as they were at first called, have proved to be one of the most interesting discoveries that science ever made. They proved what Crookes had surmised about the radiations he discovered in his vacuum tube. But it was *not* a fourth state of matter that had been found, but a new *property* of matter, a property common to all atoms of matter. The Beta rays were later christened Electrons. They are particles of disembodied electricity, here spontaneously liberated from the atoms of matter: only when the electron was isolated from the atom was it recognised for the first time as a separate entity. Electrons, therefore, are a constituent of the atoms of matter, and we have discovered that they can be released from the atom by a variety of agencies. Electrons are to be found everywhere, forming part of every atom.

"An electron," Sir William Bragg says, "can only maintain a separate existence if it is travelling at an immense rate, from one-three hundredth of the velocity of light upwards, that is to say, at least 600 *miles a second, or thereabouts.* Otherwise the electron sticks to the first atom it meets." These amazing particles may travel with the enormous velocity of from 10,000 to more than 100,000 miles a second. It was first learned that they are of an electrical nature, because they are bent out of their normal path if a magnet is brought near them. And this fact led to a further discovery: to one of those sensational estimates which the general public is apt to believe to be founded on the most

[1] The "Alpha rays" were presently recognised as atoms of helium gas, shot out at the rate of 12,000 miles a second.

The "Gamma rays" are *waves*, like the X-rays, not material particles. They appear to be a type of X-rays. They possess the remarkable power of penetrating opaque substances; they will pass through a foot of solid iron, for example.



MAGNETIC DEFLECTION OF RADIUM RAYS.

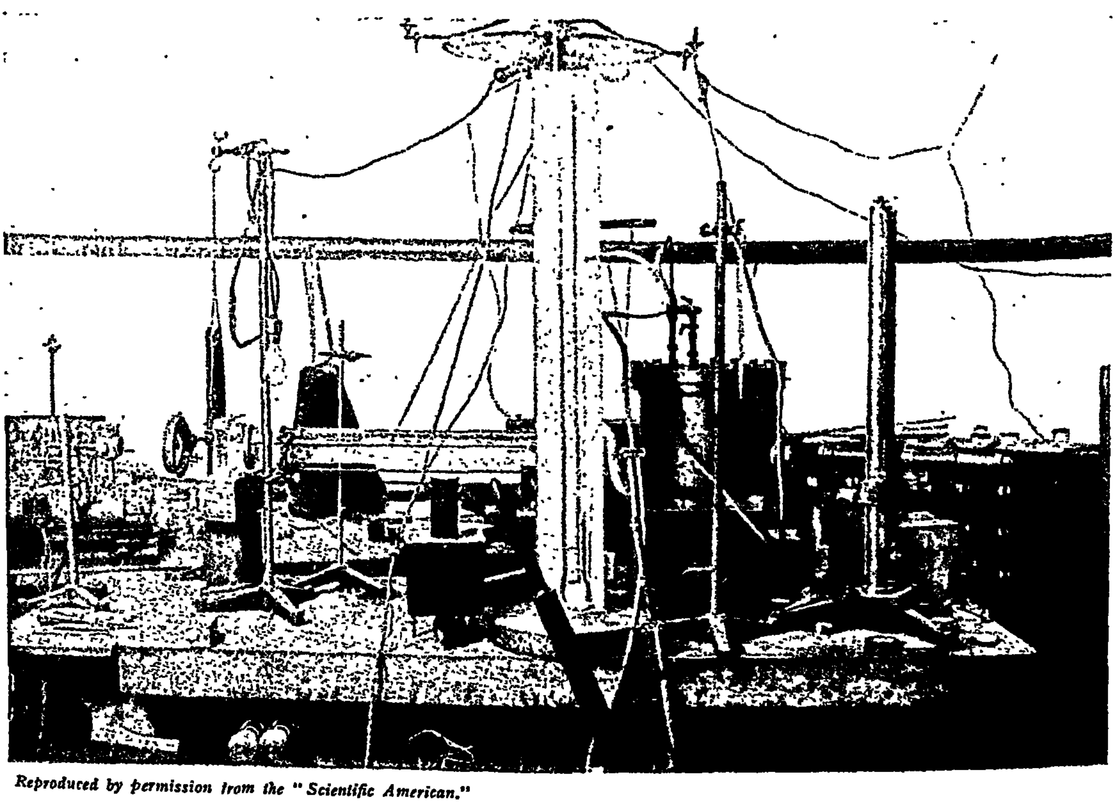
The radium rays are made to strike a screen, producing visible spots of light. When a magnetic field is applied the rays are seen to be deflected, as in the diagram. This can only happen if the rays carry an electric charge, and it was by experiments of this kind that we obtained our knowledge respecting the electric charges carried by radium rays.

abstruse speculations. The physicist set up a little chemical screen for the "Beta rays" to hit, and he so arranged his tube that only a narrow sheaf of the rays poured on to the screen. He then drew this sheaf of rays out of its course with a magnet, and he accurately measured the shift of the luminous spot on the screen where the rays impinged on it. But when he knows the exact intensity of his magnetic field—which he can control as he likes—and the amount of deviation it causes, and the mass of the moving particles, he can tell the speed of the moving particles which he thus diverts. These particles were being hurled out of the atoms of radium, or from the negative pole in a vacuum tube, at a speed which, in good conditions, reached nearly the velocity of light, i.e. nearly 186,000 miles a second.

Their speed has, of course, been confirmed by numbers of experiments; and another series of experiments enabled physicists to determine the size of the particles. Only one of these need be described, to give the reader an idea how men of science arrive at their more startling results.

Fog, as most people know, is thick in our great cities because the water-vapour gathers on the particles of dust and smoke that are in the atmosphere. This fact was used as the basis of some beautiful experiments. Artificial fogs were created in little glass tubes, by introducing dust, in various proportions, for supersaturated vapour to gather on. In the end it was possible to cause tiny drops of rain, each with a particle of dust at its core, to fall upon a silver mirror and be counted. It was a method of counting the quite invisible particles of dust in the tube; and the method was now successfully applied to the new rays. Yet another method was to direct a slender stream of the particles upon a chemical screen. The screen glowed under the cannonade of particles, and a powerful lens resolved the glow into distinct sparks, which could be counted.

In short, a series of the most remarkable and beautiful experiments, checked in all the great



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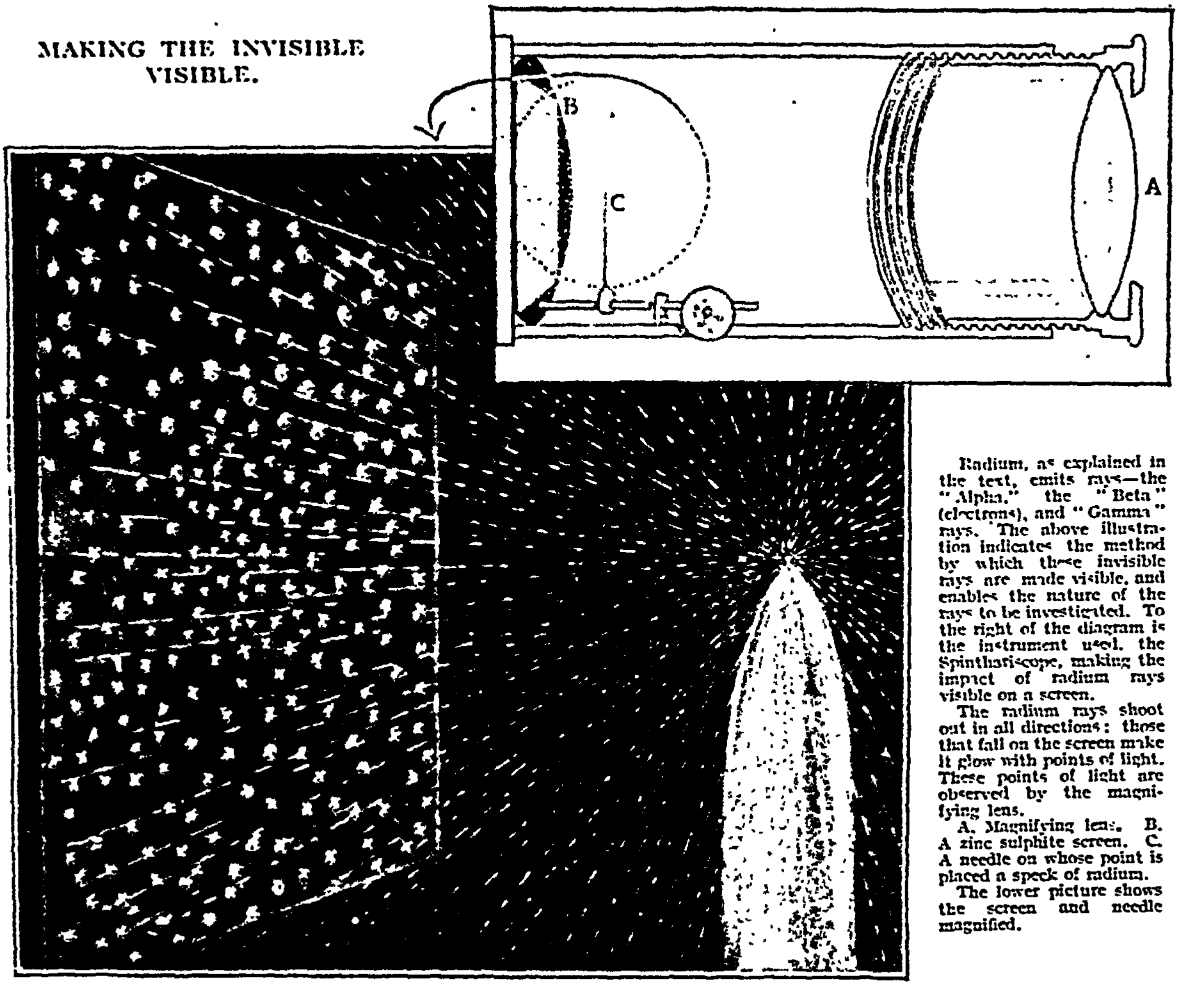
PROFESSOR R. A. MILLIKAN'S APPARATUS FOR COUNTING ELECTRONS.

MAKING THE INVISIBLE VISIBLE.



Radium, as explained in the text, emits rays—the "Alpha," the "Beta" (electrons), and "Gamma" rays. The above illustration indicates the method by which these invisible rays are made visible, and enables the nature of the rays to be investigated. To the right of the diagram is the instrument used, the Spinthariscope, making the impact of radium rays visible on a screen.

The radium rays shoot out in all directions: those that fall on the screen make it glow with points of light. These points of light are observed by the magnifying lens.

A. Magnifying lens. B. A zinc sulphite screen. C. A needle on whose point is placed a speck of radium.

The lower picture shows the screen and needle magnified.

laboratories of the world, settled the nature of these so-called rays. They were streams of particles more than a thousand times smaller than the smallest known atom. The mass of each particle is, according to the latest and finest measurements, $\frac{1}{1845}$ of that of an atom of hydrogen. The physicist has not been able to find any character except electricity in them, and the name "electrons" has been generally adopted.

The Key to many Mysteries.

The Electron is an atom, of disembodied electricity; it occupies an exceedingly small volume, and its "mass" is entirely electrical. These electrons are the key to half the mysteries of matter. Electrons in rapid motion, as we shall see, explain what we mean by an "electric current," not so long ago regarded as one of the most mysterious manifestations in nature.

"What a wonder, then, have we here!" says Professor R. K. Duncan. "An innocent-looking little pinch of salt and yet possessed of special properties utterly beyond even the fanciful imaginings of men of past time; for nowhere do we find in the records of thought even the hint of the possibility of things which we now regard as established fact. This pinch of salt projects from its surface bodies [i.e. electrons] possessing the inconceivable velocity of over 100,000 miles a second, a velocity sufficient to carry them, if unimpeded, five times around the earth in a second, and possessing with this velocity, masses a thousand times smaller than the smallest atom known to science. Furthermore, they are charged with negative electricity; they pass straight through bodies considered opaque with a sublime indifference to the properties of the body, with the exception of its mere density; they cause bodies which they strike to shine out in the

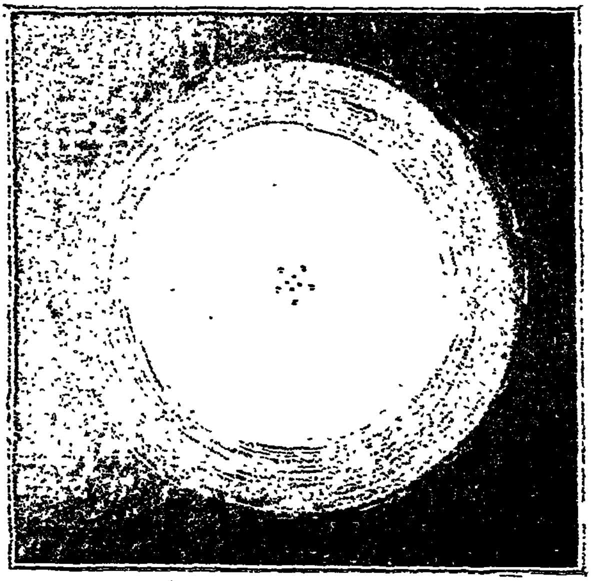
dark; they affect a photographic plate; they render the air a conductor of electricity; they cause clouds in moist air; they cause chemical action and have a peculiar physiological action. Who, to-day, shall predict the ultimate service to humanity of the beta-rays from radium!"

§ 6

THE ELECTRON THEORY, OR THE NEW VIEW OF MATTER

There is general agreement amongst all chemists, physicists, and mathematicians upon the conclusions which we have so far given. We know that the atoms of matter are constantly—either spontaneously or under stimulation—giving off electrons, or breaking up into electrons; and they therefore contain electrons. Thus we have now complete proof of the independent existence of atoms and also of electrons.

The Structure of the Atom.



THE THEORY OF ELECTRONS

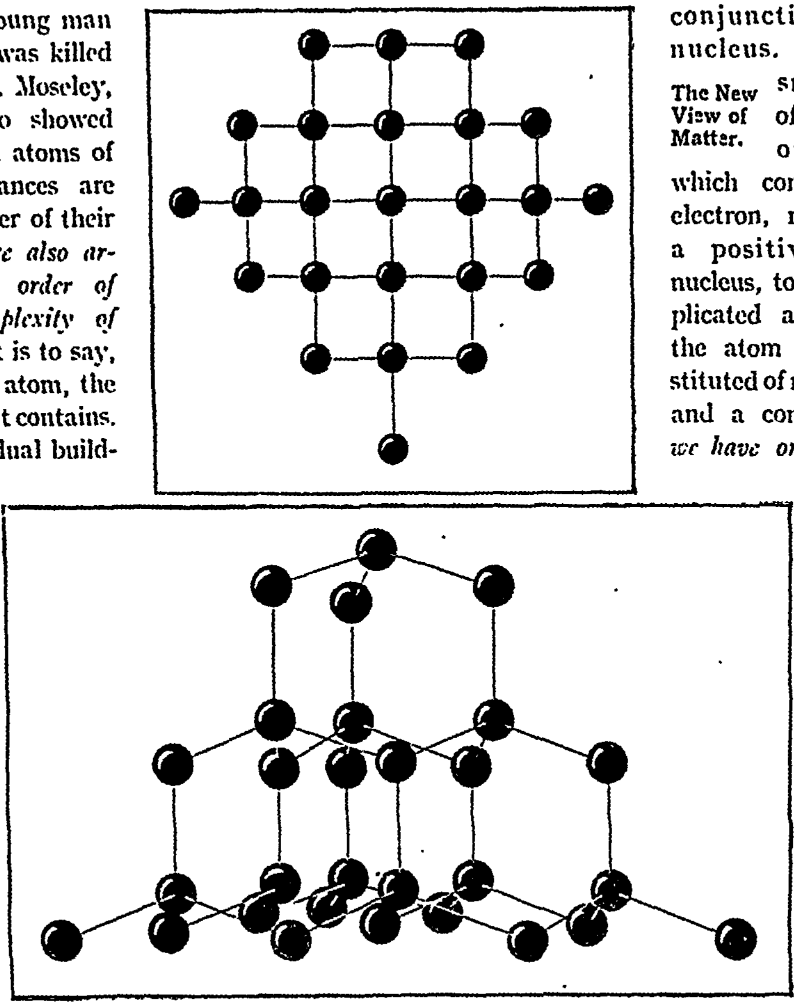
An atom of matter is composed of electrons. We picture an atom as a sort of miniature solar system, the electrons (particles of negative electricity) rotating round a central nucleus of positive electricity, as described in the text. In the above pictorial representation of an atom the whirling electrons are indicated in the outer ring. Electrons move with incredible speed as they pass from one atom to another.

When, however, the man of science tries to tell us *how* electrons compose atoms, he passes from facts to speculation, and very difficult speculation. Take the letter "o" as it is printed on this page. In a little bubble of hydrogen gas no larger than that letter there are *billions* of atoms; and they are not packed together, but are circulating as freely as dancers in a ball-room. We are asking the physicist to take one of these minute atoms and tell us how the still smaller electrons are arranged in it. Naturally he can only make mental pictures, guesses or hypotheses, which he tries to fit to the facts, and discards when they will *not* fit.

At present, after nearly twenty years of critical discussion, there are two chief theories of the structure of the atom. At first Sir J. J. Thomson imagined the electrons circulating in shells (like the layers of an onion) round the nucleus of the atom. This did not suit, and Sir E. Rutherford and others worked out a theory that the electrons circulated round a nucleus rather like the planets of our solar system revolving round the central sun. Is there a nucleus, then, round which the electrons revolve? The electron, as we saw, is a disembodied atom of electricity; we should say, of "negative" electricity. Let us picture these electrons all moving round in orbits with great velocity. Now it is suggested that there is a nucleus of "positive" electricity attracting or pulling the revolving electrons to it, and so forming an equilibrium, otherwise the electrons would fly off in all directions. This nucleus has been recently named the proton. We have thus two electricities in the atom, the positive = the nucleus; the negative = the electron. Of recent years Dr. Langmuir has put out a theory that the electrons do not *revolve round* the nucleus, but remain in a state of violent agitation of some sort at fixed distances from the nucleus.

But we will confine ourselves here to the facts, and leave the contending theories to scientific men. It is now pretty generally accepted that an atom of matter consists of a number of electrons, or charges of negative electricity, held together by a charge of positive electricity. It is not disputed that these electrons are in a state of violent motion or strain, and that therefore a vast energy is locked up in the atoms of matter. To that we will return later. Here, rather, we will notice another remarkable discovery which helps us to understand the nature of matter.

A brilliant young man of science who was killed in the war, Mr. Moseley, some years ago showed that, when the atoms of different substances are arranged in order of their weight, *they are also arranged in the order of increasing complexity of structure.* That is to say, the heavier the atom, the more electrons it contains. There is a gradual building up of atoms containing more and more electrons from the lightest atom to the heaviest. Here it is enough to say that, as he took element after element, from the lightest (hydrogen) to the heaviest (uranium), he found a strangely regular relation between them. If hydrogen were represented by the figure one, helium by two, lithium three, and so on up to uranium, then uranium should have the figure ninety-two. This makes it probable that there are in nature ninety-two elements—we have found eighty-seven—and that the number Mr. Moseley found is the number of electrons in the atom of each element; that is to say, the number is arranged in order of the atomic numbers of the various elements.



ARRANGEMENTS OF ATOMS IN A DIAMOND.

The above is a model (seen from two points of view) of the arrangement of the atoms in a diamond. The arrangement is found by studying the X-ray spectra of the diamond.

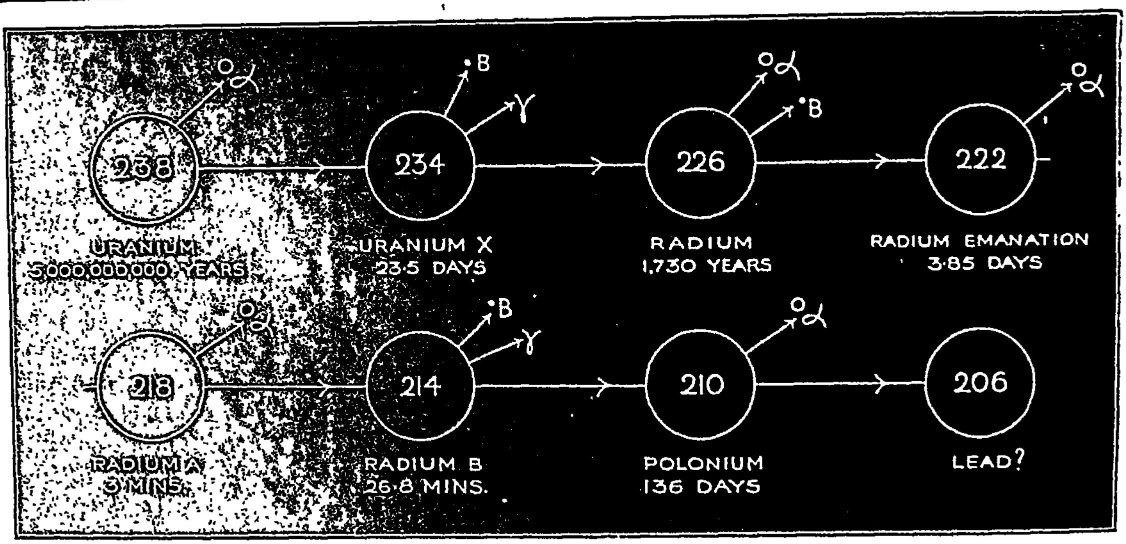
§ 7

Up to the point we have reached, then, we see what the new view of Matter is. Every atom of matter, of whatever kind throughout the whole universe, is built up of electrons in conjunction with a nucleus.

The New View of Matter.

From the smallest atom of all—the atom of hydrogen—which consists of one electron, rotating round a positively charged nucleus, to a heavy complicated atom, such as the atom of gold, constituted of many electrons and a complex nucleus, *we have only to do with positive and negative units of electricity.* The electron and its nucleus are particles of electricity. All Matter, therefore, is nothing but a manifestation of electricity. The atoms of matter, as we saw, combine and form molecules. Atoms and molecules are the bricks out of which nature has built up everything; we ourselves, the earth, the stars, the whole universe.

But more than bricks are required to build a house. There are other fundamental existences, such as the various forms of energy, which give rise to several complex problems. And we have also to remember, that there are more than eighty distinct elements, each with its own definite type of atom. We shall deal with energy later. Meanwhile it remains to be said that, although we have discovered a great deal about the electron and the constitution of matter, and that while the physicists of our own day seem to see a possibility of explaining positive and negative electricity, the nature of



DISINTEGRATION OF ATOMS.

An atom of Uranium, by ejecting an Alpha particle, becomes Uranium X. This substance, by ejecting Beta and Gamma rays, becomes Radium. Radium passes through a number of further changes, as shown in the diagram, and finally becomes lead. Some radio-active substances disintegrate much faster than others. Thus Uranium changes very slowly, taking 5,000,000,000 years to reach the same stage of disintegration that Radium A reaches in 3 minutes. As the disintegration proceeds, the substances become of lighter and lighter atomic weights. Thus Uranium has an atomic weight of 238, whereas lead has an atomic weight of only 206. The breaking down of atoms is fully explained in the text.

them both is unknown. There exists the theory that the particles of positive and negative electricity, which make up the atoms of matter, are points or centres of disturbances of some kind in a universal ether, and that all the various forms of energy are, in some fundamental way, aspects of the same primary entity which constitutes matter itself.

But the discovery of the property of radio-activity has raised many other interesting questions, besides that which we have just dealt with. In radio-active elements, such as uranium for example, the element is breaking down; in what we call radio-activity we have a manifestation of the spontaneous change of elements. What is really taking place is a transmutation of one element into another, from a heavier to a lighter. The element uranium spontaneously becomes radium, and radium passes through a number of other stages until it, in turn, becomes lead. Each descending element is of lighter atomic weight than its predecessor. The changing process, of course, is a very slow one. It may be that all matter is radio-active, or can be made so. This raises the question whether all the matter in the universe may not undergo disintegration.

There is, however, another side of the question, which the discovery of radio-activity has brought to light, and which has effected a revolution in our views. We have seen that in radio-active substances the elements are breaking down. Is there a process of building up at work? If the more complicated atoms are breaking down into simpler forms, may there not be a converse process—a building up from simpler elements to more complicated elements? It is probably the case that both processes are at work.

There are some eighty-odd chemical elements on the earth to-day: are they all the outcome of an inorganic evolution, element giving rise to element, going back and back to some primeval stuff from which they were all originally derived infinitely long ago? Is there an evolution in the inorganic world which may be going on, parallel to that of the evolution of living things; or is organic evolution a continuation of inorganic evolution? We have seen what evidence there is of this inorganic evolution in the case of the stars. We cannot go deeply into the matter here, nor has the time come for any direct statement that can be based on the findings of modern investigation. Taking it altogether the evidence is steadily accumulating, and there are authorities

who maintain that already the evidence of inorganic evolution is convincing enough. The heavier atoms would appear to behave as though they were evolved from the lighter. The more complex forms, it is supposed, have *evolved* from the simpler forms. Moseley's discovery, to which reference has been made, points to the conclusion that the elements are built up one from another.

§ 8

Other New Views.

We may here refer to another new conception to which the discovery of radio-activity has given rise. Lord Kelvin, who estimated the age of the earth at twenty million years, reached this estimate by considering the earth as a body which is gradually cooling down, "losing its primitive heat, like a loaf taken from the oven, at a rate which could be calculated, and that the heat radiated by the sun was due to contraction." Uranium and radio-activity were not known to Kelvin, and their discovery has upset both his arguments. Radio-active substances, which are perpetually giving out heat, introduce an entirely new factor. We cannot now assume that the earth is necessarily cooling down; it may even, for all we know, be getting hotter. At the 1921 meeting of the British Association, Professor Rayleigh stated that further knowledge had extended the probable period during which there had been life on this globe to about one thousand million years, and the total age of the earth to some small multiple of that. The earth, he considers, is not cooling, but "contains an internal source of heat from the disintegration of uranium in the outer crust." On the whole the estimate obtained would seem to be in agreement with the geological estimates. The question, of course, cannot, in the present state of our knowledge, be settled within fixed limits that meet with general agreement.

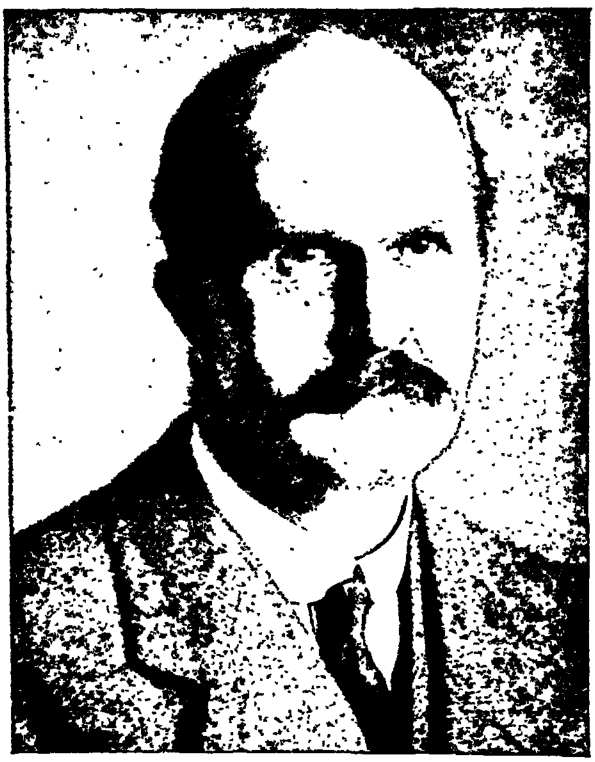


Photo: Photo Press.

PROFESSOR SIR W. H. BRAGG.

One of the most distinguished physicists of the present day.

As we have said, there are other fundamental existences which give rise to more complex problems. The three great fundamental entities in the physical universe are matter, ether, and energy; so far as we know, outside these there is nothing. We have dealt with matter, there remain ether and energy. We shall see that just as no particle of matter, however small, may not be created or destroyed, and just as there is no such thing as empty space—ether pervades everything—so there is no such thing as *rest*. Every particle that goes to make up our solid earth is in a state of perpetual unremitting vibration; energy "is the universal commodity on which all life depends." Separate and distinct as these three fundamental entities—matter, ether, and energy—may appear, it may be that, after all, they are only different and mysterious phases of an essential "oneness" of the universe.

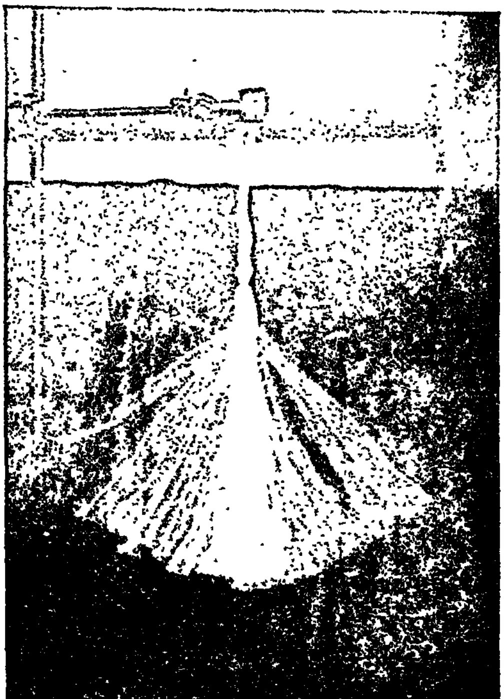
§ 9

The Future.

Let us, in concluding this chapter, give just one illustration of the way in which all this new knowledge may prove to be as valuable practically as it is wonderful intellectually. We saw that electrons are shot out of atoms at a speed that may approach 160,000 miles a second. Sir Oliver Lodge has written recently that a

seventieth of a grain of radium discharges, at a speed a thousand times that of a rifle bullet, thirty million electrons a second. Professor Le Bon has calculated that it would take 1,340,000 barrels of powder to give a bullet the speed of one of these electrons. He shows that the smallest French copper coin—smaller than a farthing—contains an energy equal to eighty million horse-power. A few pounds of matter contain more energy than we could extract from millions of tons of coal. Even in the atoms of hydrogen at a temperature which we could produce in an electric furnace the electrons spin round at a rate of nearly a hundred billion revolutions a second!

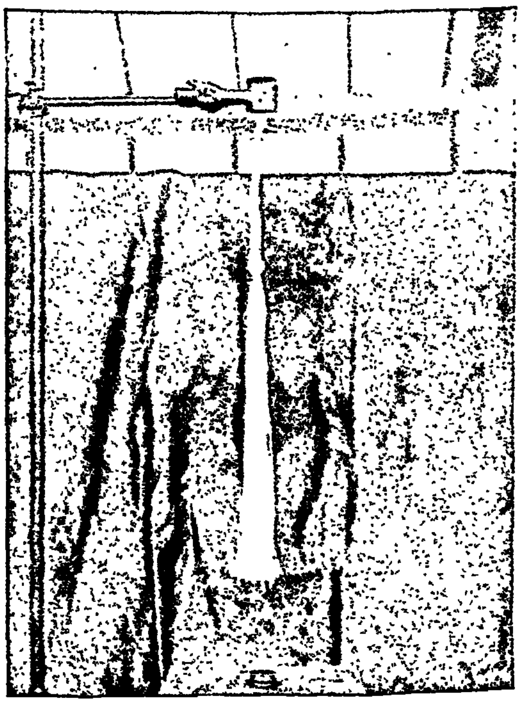
Every man asks at once: "Will science ever tap this energy?" If it does, no more smoke, no mining, no transit, no bulky fuel. The energy of an atom is of course only liberated when an atom passes from one state to another. The stored up energy is fortunately fast bound by the electrons being held together as has been described. If it were not so "the earth would explode and become a gaseous nebula"! It is believed that some day we shall be able to release, harness, and utilise atomic energy. "I am of opinion," says Sir William Bragg, "that atom energy will supply our future need. A thousand years may pass before we can harness the atom, or to-morrow might see us with the reins in our hands. That is the peculiarity of Physics—research and 'accidental' discovery go hand in hand." Half a brick contains as much energy as a small coal-field. The difficulties are tremendous, but, as Sir Oliver Lodge reminds us, there was just as much scepticism at one time about the utilisation of steam or electricity. "Is it to be supposed," he asks, "that there can be no fresh invention, that all the great discoveries have been made?" More than one man of science encourages us to hope Here are some remarkable words written by Professor Soddy, one of the highest authorities on radio-active matter, in our chief scientific weekly (*Nature*, November 6, 1919):



Reproduced by permission from "The Interpretation of Radium" (John Murray).

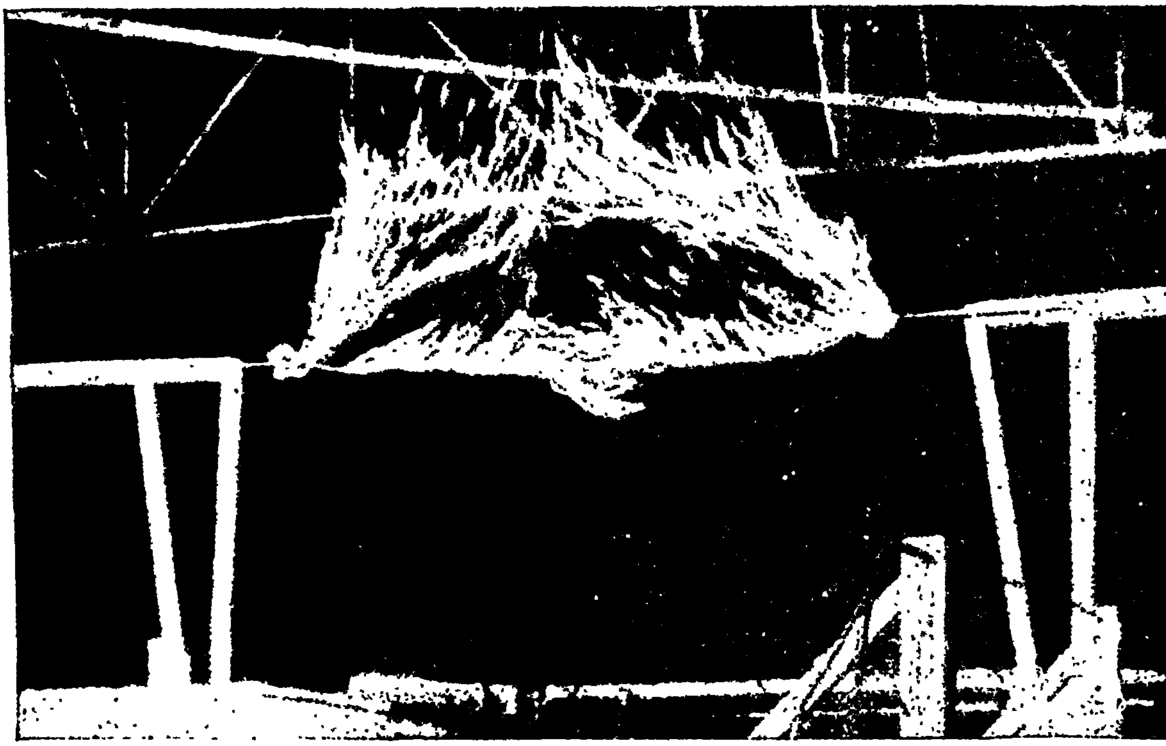
SILK TASSEL ELECTRIFIED.

The separate threads of the tassel, being each electrified with the same kind of electricity, repel one another, and thus the tassel branches out as in the photograph.



SILK TASSEL DISCHARGED BY THE RAYS FROM RADIUM.

When the radium rays, carrying an opposite electric charge to that on the tassel, strikes the threads, the threads are neutralised, and hence fall together again.



A HUGE ELECTRIC SPARK.

This is an actual photograph of an electric spark. It is leaping a distance of about 10 feet, and is the discharge of a million volts. It is a graphic illustration of the tremendous energy of electrons.

"The prospects of the successful accomplishment of artificial transmutation brighten almost daily. The ancients seem to have had something more than an inkling that the accomplishment of transmutation would confer upon men powers hitherto the prerogative of the gods. But now we know definitely that the material aspect of transmutation would be of small importance in comparison with the control over the inexhaustible stores of internal atomic energy to which its successful accomplishment would inevitably lead. It has become a problem, no longer redolent of the evil associations of the age of alchemy, but one big with the promise of a veritable physical renaissance of the whole world."

If that "promise" is ever realised, the economic and social face of the world will be transformed.

Before passing on to the consideration of ether, light, and energy, let us see what new light the discovery of the electron has thrown on the nature and manipulation of electricity.

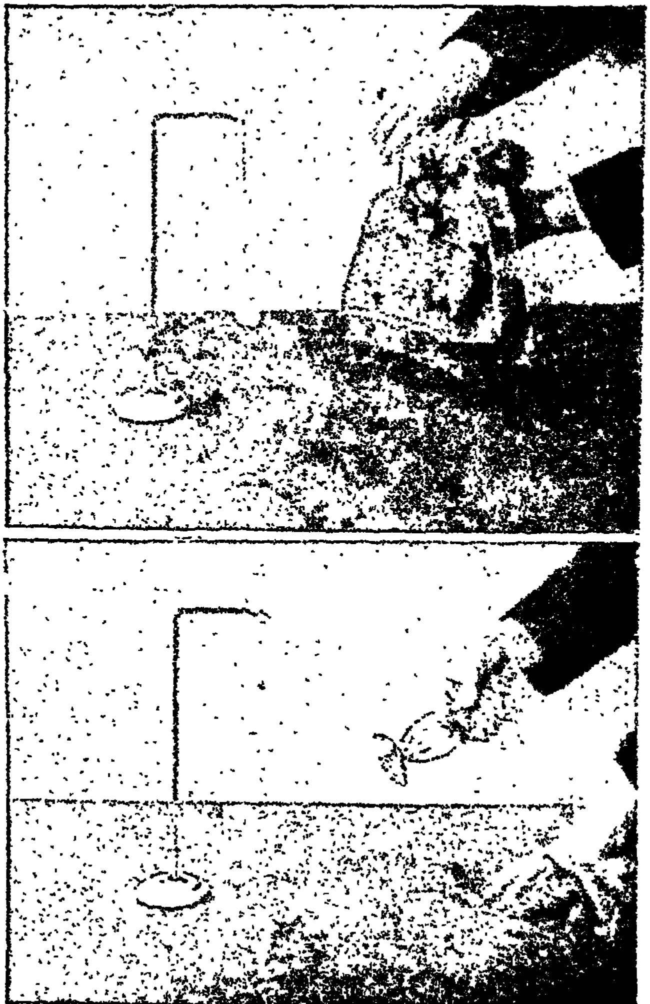
WHAT IS ELECTRICITY?

The Nature of Electricity.

There is at least one manifestation in nature, and so late as twenty years ago it seemed to be one of the most mysterious manifestations of all, which has been in great measure explained by the new discoveries. Already, at the beginning of this century, we spoke of our "age of electricity," yet there were few things in nature about which we knew less. The "electric current" rang our bells, drove our trains, lit our rooms, but none knew what the current was. There was a vague idea that it was a sort of fluid that flowed along copper wires as water flows in a pipe. We now suppose that it is *a rapid movement of electrons from atom to atom* in the wire or wherever the current is.

Let us try to grasp the principle of the new view of electricity and see how it applies to all the varied electrical phenomena in the world about us. As we saw, the nucleus of an atom of matter consists of positive electricity which holds together a number of electrons, or charges

of negative electricity.[1] This certainly tells us to some extent what electricity is, and how it is related to matter, but it leaves us with the usual difficulty about fundamental realities. But we now know that electricity, like matter, is atomic in structure; a charge of electricity is made up of a number of small units or charges of a definite, constant amount. It has been suggested that the two kinds of electricity, i.e. positive and negative, are right-handed and left-handed vortices or whirlpools in ether, or rings in ether, but there are very serious difficulties, and we leave this to the future.



From "Scientific Ideas of To-day."

ELECTRICAL ATTRACTION BETWEEN COMMON OBJECTS.

Take an ordinary flower-vase, well dried, and energetically rub it with a silk handkerchief. The vase, which thus becomes electrified, will attract any light body, such as a feather, as shown in the above illustration.

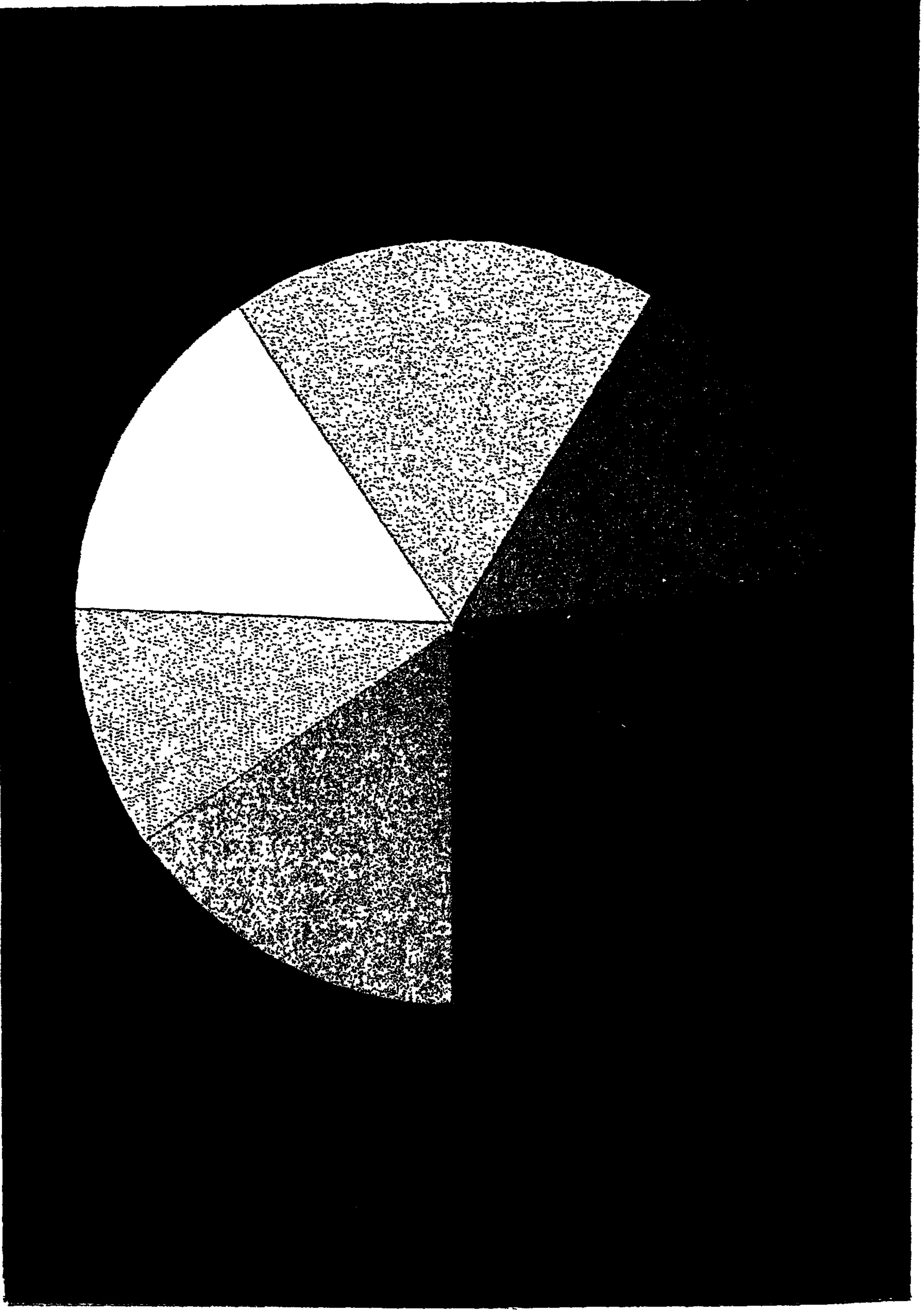
§ 10

What an Electric Current is.

The discovery of these two kinds of electricity has, however, enabled us to understand very fairly what goes on in electrical phenomena. The outlying electrons, as we saw, may pass from atom to atom, and this, on a large scale, is the meaning of the electric current. In other words, we believe an electric current to be a flow of electrons. Let us take, to begin with, a simple electrical "cell," in which a feeble current is generated: such a cell as there is in every house to serve its electric bells.

In the original form this simple sort of "battery" consisted of a plate of zinc and a plate of copper immersed in a chemical. Long before anything was known about electrons it was known that, if you put zinc and copper together, you produce a mild current of electricity. We know now what this means. Zinc is a metal the atoms of which are particularly disposed to part with some of their outlying electrons. Why, we do not know; but the fact is the basis of these small batteries. Electrons from the atoms of zinc pass to the atoms of copper, and their passage is a "current." Each atom gives up an electron to its neighbour. It was further found long ago that if the zinc and copper were immersed in certain chemicals, which slowly dissolve the zinc, and the two metals were connected by a copper wire, the current was stronger. In modern language, there is a brisker flow of electrons. The reason is that the atoms of zinc which are stolen by the chemical leave their detachable electrons behind them, and the zinc has therefore more electrons to pass on to the copper.

[1] The words "positive" and "negative" electricity belong to the days when it was regarded as a fluid. A body overcharged with the fluid was called positive; an undercharged body was called negative. A positively-electrified body is now one whose atoms have lost some of their outlying electrons, so that the positive charge of electricity predominates. The negatively-electrified body is one with more than the normal number of electrons.



ROTATING DISC OF SIR ISAAC NEWTON FOR MIXING COLOURS

The Spectroscope sorts out the above seven colours from sunlight (which is compounded of these seven colours). If painted in proper proportions on a wheel, as shown in the coloured illustration, and the wheel be turned rapidly on a pivot through its centre, only a dull white will be perceived. If one colour be omitted, the result will be one colour —the result of the union of the remaining six.

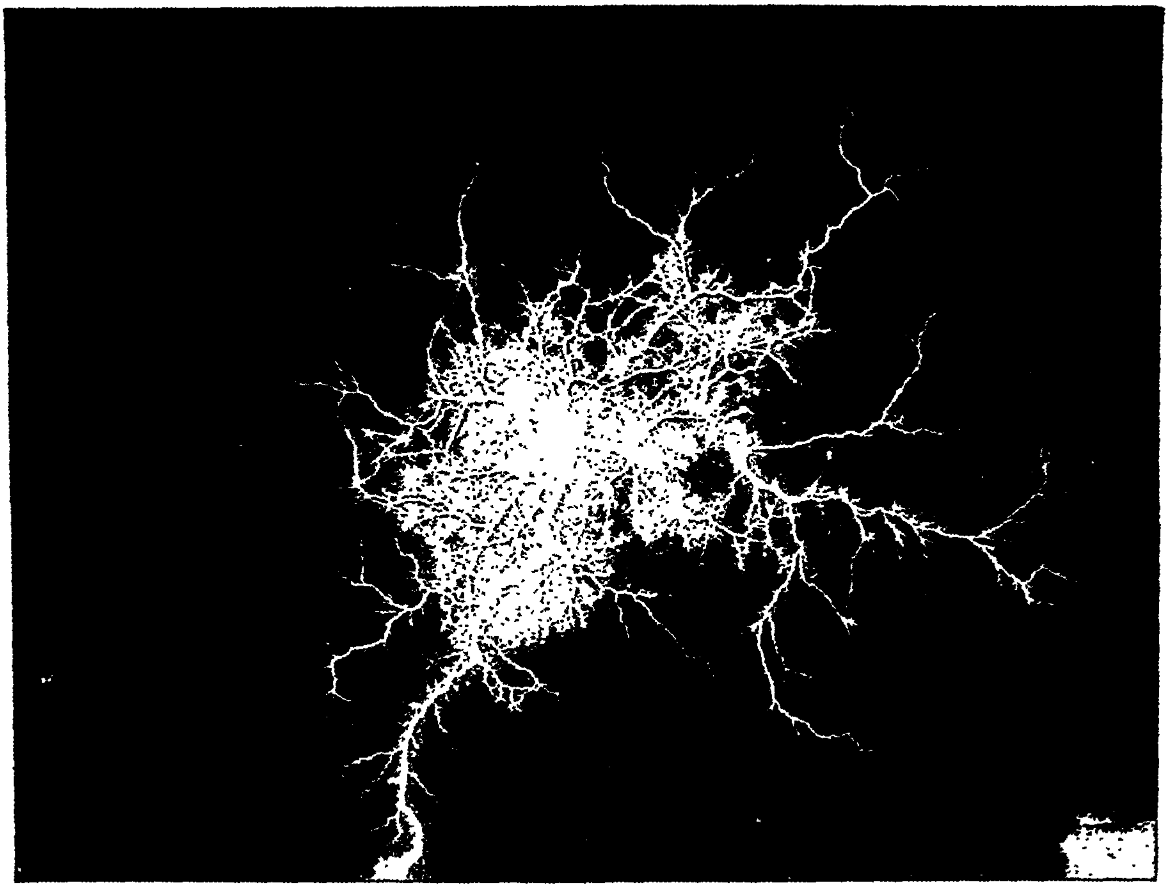


Photo: Leadbeater.

AN ELECTRIC SPARK.

An electric spark consists of a rush of electrons across the space between the two terminals. A state of tension is established in the ether by the electric charges, and when this tension passes a certain limit the discharge takes place.

Such cells are now made of zinc and carbon, immersed in sal-ammoniac, but the principle is the same. The flow of electricity is a flow of electrons; though we ought to repeat that they do not flow in a body, as molecules of water do. You may have seen boys place a row of bricks, each standing on one end, in such order that the first, if it is pushed, will knock over the second, the second the third, and so on to the last. There is a flow of *movement* all along the line, but each brick moves only a short distance. So an electron merely passes to the next atom, which sends on an electron to a third atom, and so on. In this case, however, the movement from atom to atom is so rapid that the ripple of movement, if we may call it so, may pass along at an enormous speed. We have seen how swiftly electrons travel.

But how is this turned into power enough even to ring a bell? The actual mechanical apparatus by which the energy of the electron current is turned into sound, or heat, or light will be described in a technical section later in this work. We are concerned here only with the principle, which is clear. While zinc is very apt to part with electrons, copper is just as obliging in facilitating their passage onward. Electrons will travel in this way in most metals, but copper is one of the best "conductors." So we lengthen the copper wire between the zinc and the carbon until it goes as far as the front door and the bell, which are included in the circuit. When you press the button at the door, two wires are brought together, and the current of electrons rushes round the circuit; and at the bell its energy is diverted into the mechanical apparatus which rings the bell.

Copper is a good conductor—six times as good as iron—and is therefore so common in electrical industries. Some other substances are just as stubborn as copper is yielding, and we call them "insulators," because they resist

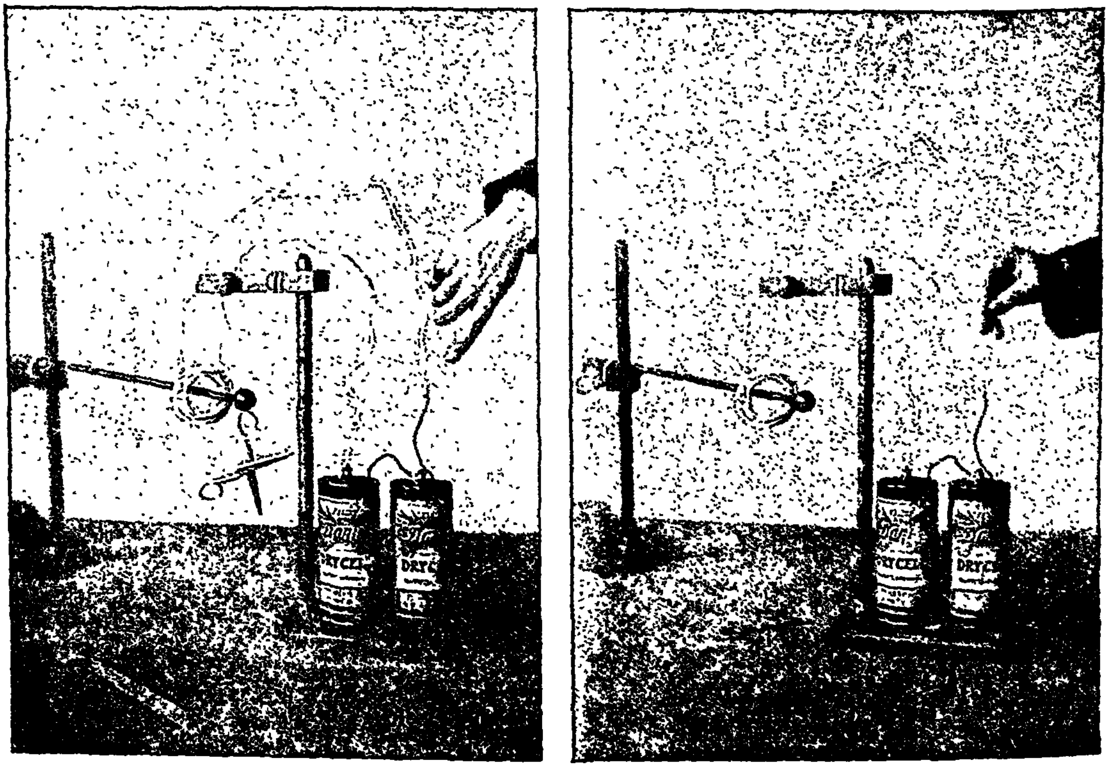
the current instead of letting it flow. Their atoms do not easily part with electrons. Glass, vulcanite, and porcelain are very good insulators for this reason.

What the Dynamo does.

But even several cells together do not produce the currents needed in modern industry, and the flow is produced in a different manner. As the invisible electrons pass along a wire they produce what we call a magnetic field around the wire, they produce a disturbance in the surrounding ether. To be exact, it is through the ether surrounding the wire that the energy originated by the electrons is transmitted. To set electrons moving on a large scale we use a "dynamo." By means of the dynamo it is possible to transform mechanical energy into electrical energy. The modern dynamo, as Professor Soddy puts it, may be looked upon as an electron pump. We cannot go into the subject deeply here, we would only say that a large coil of copper wire is caused to turn round rapidly between the poles of a powerful magnet. That is the essential construction of the "dynamo," which is used for generating strong currents. We shall see in a moment how magnetism differs from electricity, and will say here only that round the poles of a large magnet there is a field of intense disturbance which will start a flow of electrons in any copper that is introduced into it. On account of the speed given to the coil of wire its atoms enter suddenly this magnetic field, and they give off crowds of electrons in a flash.

It is found that a similar disturbance is caused, though the flow is in the *opposite* direction, when the coil of wire leaves the magnetic field. And as the coil is revolving very rapidly we get a powerful current of electricity that runs in alternate directions—an "alternating" current. Electricians have apparatus for converting it into a continuous current where this is necessary.

A current, therefore, means a steady flow of



From "Scientific Ideas of To-day."

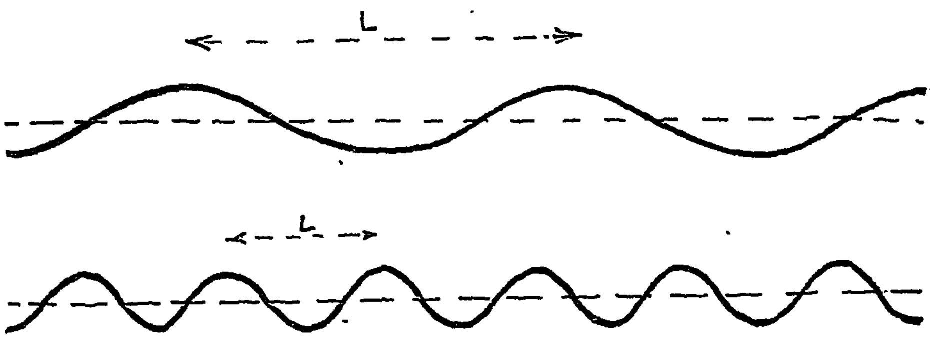
AN ETHER DISTURBANCE AROUND AN ELECTRON CURRENT.

In the left-hand photograph an electric current is passing through the coil, thus producing a magnetic field and transforming the poker into a magnet. The poker is then able to support a pair of scissors. As soon as the electric current is broken off, as in the second photograph the ether disturbance ceases. The poker loses its magnetism, and the scissors fall.

Photo: H. J. Shepstone.

LIGHTNING.

In a thunderstorm we have the most spectacular display in lightning of a violent and explosive rush of electrons (electricity) from one body to another, from cloud to cloud, or to the earth. In this wonderful photograph of an electrical storm note the long branched and undulating flashes of lightning. Each flash lasts no longer than the one hundred-thousandth part of a second of time



LIGHT WAVES.

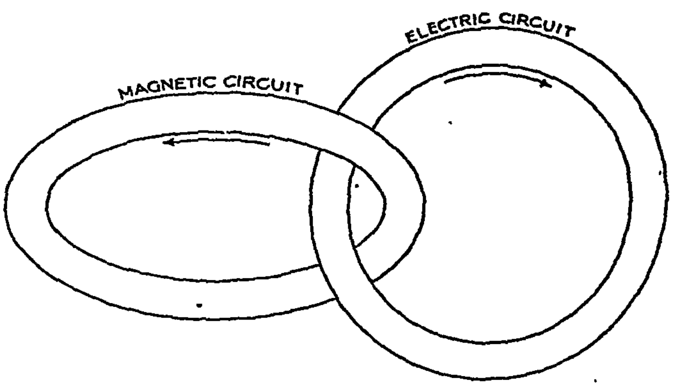
Light consists of waves transmitted through the ether. Waves of light differ in length. The colour of the light depends on the wave-length. Deep-red waves (the longest) are $\frac{1}{33000}$ inch and deep-violet waves $\frac{1}{67000}$ inch. The diagram shows two wave-motions of different wave-lengths. From crest to crest, or from trough to trough, is the length of the wave.

the electrons from atom to atom. Sometimes, however, a number of electrons rush violently and explosively from one body to another, as in the electric spark or the occasional flash from an electric tram or train. The grandest and most spectacular display of this phenomenon is the thunder-storm. As we saw earlier, a portentous furnace like the sun is constantly pouring floods of electrons from its atoms into space. The earth intercepts great numbers of these electrons. In the upper regions of the air the stream of solar electrons has the effect of separating positively-electrified atoms from negatively-electrified ones, and the water-vapour, which is constantly rising from the surface of the sea, gathers more freely round the positively-electrified atoms, and brings them down, as rain, to the earth. Thus the upper air loses a proportion of positive electricity, or becomes "negatively electrified." In the thunderstorm we get both kinds of clouds—some with large excesses of electrons, and some deficient in electrons—and the tension grows until at last it is relieved by a sudden and violent discharge of electrons from one cloud to another or to the earth—an electric spark on a prodigious scale.

§ 11

Magnetism.

We have seen that an electric current is really a flow of electrons. Now an electric current exhibits a magnetic effect. The surrounding space is endowed with energy which we call electro-magnetic energy. A piece of magnetised iron attracting other pieces of iron to it is the popular idea of a magnet. If we arrange a wire to pass vertically through a piece of cardboard and then sprinkle iron filings on the cardboard we shall find that, on passing an electric current through the wire, the iron filings arrange themselves in circles round it. The magnetic force, due to the electric current, seems to exist in circles round the wire, an ether disturbance being set up. Even a single electron, when in movement, creates a magnetic "field," as it is called, round its path. There is no movement of electrons without this attendant field of energy, and their motion is not stopped until that field of energy disappears from the ether. The modern theory of magnetism supposes that all magnetism is produced in this way. All



THE MAGNETIC CIRCUIT OF AN ELECTRIC CURRENT.

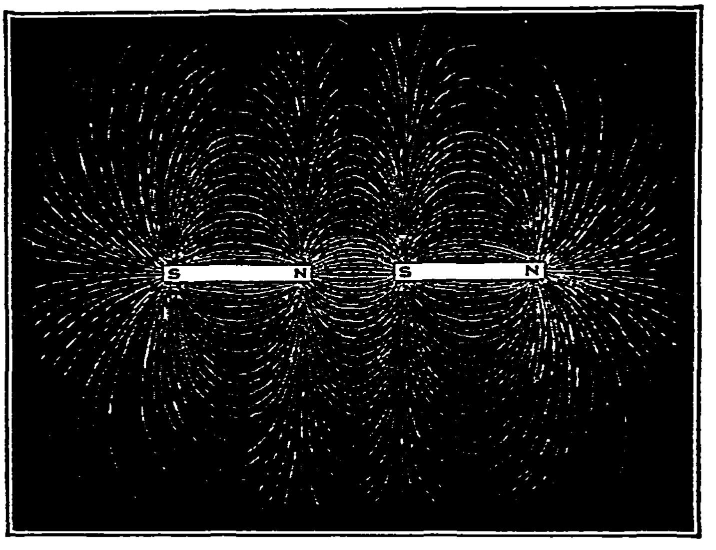
The electric current passing, in the direction of the arrow, round the electric circuit generates in the surrounding space circular magnetic circuits as shown in the diagram. It is this property which lies at the base of the electro-magnet and of the electric dynamo.

magnetism is supposed to arise from the small whirling motions of the electrons contained in the ultimate atoms of matter. We cannot here go into the details of the theory nor explain why, for instance, iron behaves so differently from other substances, but it is sufficient to say that here, also, the electron theory provides the key. This theory is not yet definitely *proved*, but it furnishes a sufficient theoretical basis for future research. The earth itself is a gigantic magnet, a fact which makes the compass possible, and it is well known that the earth's magnetism is affected by those great outbreaks on the sun called sun-spots. Now it has been recently shown that a sun-spot is a vast whirlpool of electrons and that it exerts a strong magnetic action. There is doubtless a connection between these outbreaks of electronic activity and the consequent changes in the earth's magnetism. The precise mechanism of the connection, however, is still a matter that is being investigated.

ETHER AND WAVES

Ether and Waves.

The whole material universe is supposed to be embedded in a vast medium called the ether. It is true that the notion of the ether has been abandoned by some modern physicists, but, whether or not it is ultimately dispensed with, the conception of the ether has entered so deeply into the scientific mind that the science of physics cannot be understood unless we know something about the properties attributed to the ether. The ether was invented to explain the phenomena of light, and to account for the flow of energy across empty space. Light takes time to travel. We do not see the sun rise until eight minutes after it has risen. It has taken that eight minutes for the light from the sun to travel that 93,000,000 miles odd which separates it from our earth. Besides the fact that light takes time to travel, it can be shown that light travels in the form of waves. We know that sound travels in waves; sound consists of waves in the air, or water or wood or whatever medium we hear it through. If an electric bell be put in a glass jar and the air be pumped out of the jar, the sound of the bell becomes feebler and feebler until, when enough air has been taken out, we do not hear the bell at all. Sound cannot travel in a vacuum. We continue to *see* the bell, however, so that evidently light can travel in a vacuum. The invisible medium through which the waves of light travel is the ether, and this ether permeates all space *and all matter*. Between us and the stars stretch vast regions empty of all matter.



THE MAGNET.

The illustration shows the lines of force between two magnets. The lines of force proceed from the north pole of one magnet to the south pole of the other. They also proceed from the north to the south poles of the same magnet. These facts are shown clearly in the diagram. The north pole of a magnet is that end of it which turns to the north when the magnet is freely suspended.

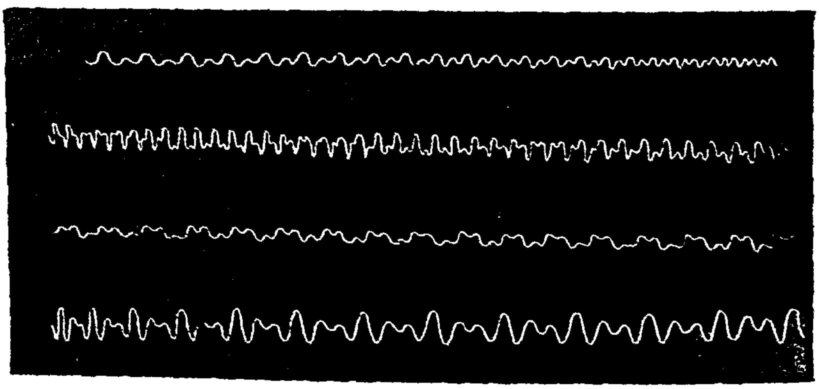
But we see the stars; their light reaches us, even though it may take centuries to do so. We conceive, then, that it is the universal ether which conveys that light. All the energy which has reached the earth from the sun and which, stored for ages in our coal-fields, is now used to propel our trains and steamships, to heat and light our cities, to perform all the multifarious tasks of modern life, was conveyed by the ether. Without that universal carrier of energy we should have nothing but a stagnant, lifeless world.

We have said that light consists of waves. The ether may be considered as resembling, in

some respects, a jelly. It can transmit vibrations. The waves of light are really excessively small ripples, measuring from crest to crest. The distance from crest to crest of the ripples in a pond is sometimes no more than an inch or two. This distance is enormously great compared to the longest of the wave-lengths that constitute light. We say the longest; for the waves of light differ in length; the colour depends upon the length of the light. Red light has the longest waves and violet the shortest. The longest waves, the waves of deep-red light, are seven two hundred and fifty thousandths of an inch in length ($\frac{7}{250,000}$ inch). This is nearly twice the length of deep-violet light-waves, which are $\frac{1}{67,000}$ inch. But light-waves, the waves that affect the eye, are not the only waves carried by the ether. Waves too short to affect the eye can affect the photographic plate, and we can discover in this way the existence of waves only half the length of the deep-violet waves. Still shorter waves can be discovered, until we come to those excessively minute rays, the X-rays.

Below the Limits of Visibility.

But we can extend our investigations in the other direction; we find that the ether carries many waves longer than light-waves. Special photographic emulsions can reveal the existence of waves five times longer than violet-light waves. Extending below the limits of visibility are waves we detect as heat-waves. Radiant heat, like the heat from a fire, is also a form of wave-motion in the ether, but the waves our senses recognise as heat are longer than light-waves. There are longer waves still, but our senses do not recognise them. But we can detect them by our instruments. These are the waves used in wireless telegraphy, and their length may be, in some cases, measured in miles. These waves are the so-called electro-magnetic waves. Light, radiant heat, and electro-magnetic waves are all of the same nature; they differ only as regards their wave-lengths.



WAVE SHAPES.

Wave-motions are often complex. The above illustration shows some fairly complicated wave shapes. All such wave-motions can be produced by superposing a number of simple wave forms.

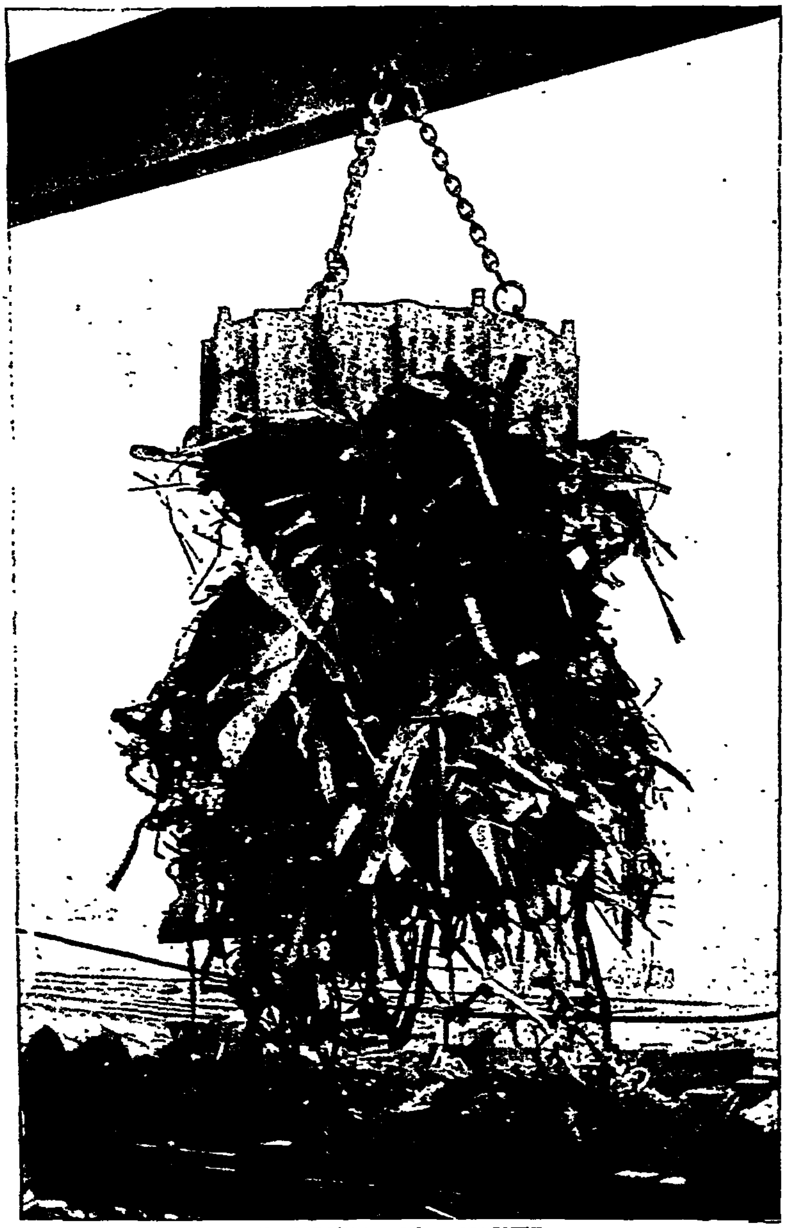
LIGHT—VISIBLE AND INVISIBLE

If Light, then, consists of waves transmitted through the ether, what gives rise to the waves? Whatever sets up such wonderfully rapid series of waves must be something with an enormous vibration. We come back to the electron: all atoms of matter, as we have seen, are made up of electrons revolving in a regular orbit round a nucleus. These electrons may be affected by outside influences, they may be agitated and their speed or vibration increased.

Electrons and Light.

The particles even of a piece of cold iron are in a state of vibration. No nerves of ours are able to feel and register the waves they emit, but your cold poker is really radiating, or sending out a series of wave-movements, on every side. After what we saw about the nature of matter, this will surprise none. Put your poker in the fire for a time. The particles of the glowing coal, which are violently agitated, communicate some of their energy to the particles of iron in the poker. They move to and fro more rapidly, and the

waves which they create are now able to affect your nerves and cause a sensation of heat. Put the poker again in the fire, until its temperature rises to 500° C. It begins to glow with a dull red. Its particles are now moving very violently, and the waves they send out are so short and rapid that they can be picked up by the eye—we have *visible* light. They would still not affect a photographic plate. Heat the iron further, and the crowds of electrons now send out waves of various lengths which blend into white light. What is happening is the agitated electrons flying round in their orbits at a speed of billions of times a second. Make the iron "blue hot," and it pours out, in addition to light, the *invisible* waves which alter the film on the photographic plate. And beyond these there is a long range of still shorter waves, culminating in the X-rays, which will pass between the atoms of flesh or stone.



THE POWER OF A MAGNET.
The illustration is that of a "Phœnix" electric magnet lifting scrap from railway trucks. The magnet is 52 inches in diameter and lifts a weight of 26 tons. The same type of magnet, 62 inches in diameter, lifts a weight of 40 tons.

Nearly two hundred and fifty years ago it was proved that light travelled at least 600,000 times faster than sound. Jupiter, as we saw, has moons, which circle round it. They pass behind the body of the planet, and reappear at the other side. But it was noticed that, when Jupiter is at its greatest distance from us, the reappearance of the moon from behind it is 16 minutes and 36 seconds later than when the planet is nearest to us. Plainly this was because light took so long to cover the additional distance. The distance was then imperfectly known, and the speed of light was underrated. We now know the distance, and we easily get the velocity of light.

No doubt it seems far more wonderful to discover this within the walls of a laboratory, but it was done as long ago as 1850. A cogged wheel is so mounted that a ray of light passes between two of the teeth and is reflected back from a mirror. Now, slight as is the fraction of a second which light takes to travel that distance, it is possible to give such speed to the wheel that the next tooth

Photo: The Locomotive Publishing Co., Ltd.

THE SPEED OF LIGHT.

A train travelling at the rate of sixty miles per hour would take rather more than seventeen and a quarter days to go round the earth at the equator, i.e. a distance of 25,000 miles. Light, which travels at the rate of 186,000 miles per second, would take between one seventh and one-eighth of a second to go the same distance.

catches the ray of light on its return and cuts it off. The speed is increased still further until the ray of light returns to the eye of the observer through the notch *next* to the one by which it had passed to the mirror! The speed of the wheel was known, and it was thus possible again to gather the velocity of light. If the shortest waves are $\frac{1}{67,000}$ of an inch in length, and light travels at 186,000 miles a second, any person can work out that about 800 billion waves enter the eye in a second when we see "violet."

Sorting out Light-waves. The waves sent out on every side by the energetic electrons become faintly visible to us when they reach about $\frac{1}{35,000}$ of an inch. As they become shorter and more rapid, as the electrons increase their speed, we get, in succession, the colours red, orange, yellow, green, blue, indigo, and violet. Each distinct sensation of colour means a wave of different length. When they are all mingled together, as in the light of the sun, we get white light. When this white light passes through glass, the speed of the waves is lessened; and, if the ray of light falls obliquely on a triangular piece of glass, the waves of different lengths part company as they travel through it, and the light is spread out in a band of rainbow-colour. The waves are sorted out according to their lengths in the "obstacle race" through the glass. Anyone may see this for himself by holding up a wedge-shaped piece of crystal between the sunlight and the eye; the prism separates the sunlight into its constituent colours, and these various colours will be seen quite readily. Or the thing may be realised in another way. If the seven colours are painted on a wheel as shown on page 209 (in the proportion shown), and the wheel rapidly revolved on a pivot, the wheel will appear a dull white, the several colours will not be seen. But *omit* one of the colours, then the wheel, when revolved, will not appear

white, but will give the impression of one colour, corresponding to what the union of six colours gives. Another experiment will show that some bodies held up between the eye and a white light will not permit all the rays to pass through, but will intercept some; a body that intercepts all the seven rays except red will give the impression of red, or if all the rays except violet, then violet will be the colour seen.

The Fate of the World.

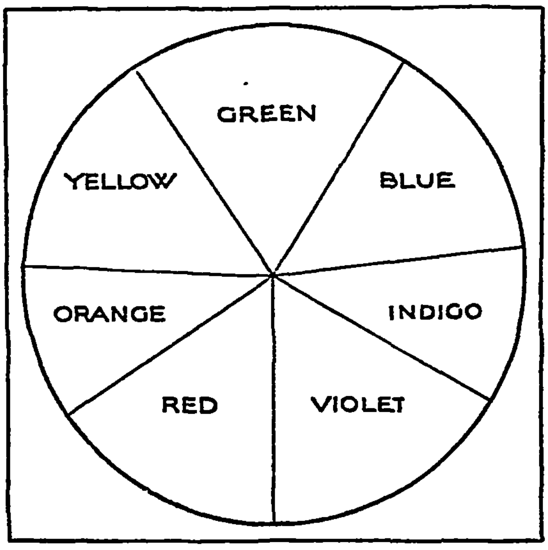
Professor Soddy has given an interesting picture of what might happen when the sun's light and heat is no longer what it is. The human eye "has adapted itself through the ages to the peculiarities of the sun's light, so as to make the most of that wave-length of which there is most. . . . Let us indulge for a moment in these gloomy prognostications, as to the consequences to this earth of the cooling of the sun with the lapse of ages, which used to be in vogue, but which radioactivity has so rudely shaken. Picture the fate of the world when the sun has become a dull red-hot ball, or even when it has cooled so far that it would no longer emit light to us. That does not all mean that the world would be in inky darkness, and that the sun would not emit light to the people then inhabiting this world, if any had survived and could keep themselves from freezing. To such, if the eye continued to adapt itself to the changing conditions, our blues and violets would be ultra-violet and invisible, but our dark heat would be light and hot bodies would be luminous to them which would be dark to us."

§ 12

What the Blue "Sky" means.

We saw in a previous chapter how the spectroscope splits up light-waves into their colours. But nature is constantly splitting the light into its different-lengthed waves, its colours. The rainbow, where dense moisture in the air acts as a spectroscope, is the most familiar example. A piece of mother-of-pearl, or even a film of oil on the street or on water, has the same effect, owing to the fine inequalities in its surface. The atmosphere all day long is sorting out the waves. The blue "sky" overhead means that the fine particles in the upper atmosphere catch the shorter waves, the blue waves, and scatter them. We can make a tubeful of blue sky in the laboratory at any time. The beautiful pink-flush on the Alps at sunrise, the red glory that lingers in the west at sunset, mean that, as the sun's rays must struggle through denser masses of air when it is low on the horizon, the long red waves are sifted out from the other shafts.

Then there is the varied face of nature which, by absorbing some waves and reflecting others, weaves its own beautiful robe of colour. Here and there is a black patch, which *absorbs* all the light. White surfaces *reflect* the whole of it.



ROTATING DISC OF SIR ISAAC NEWTON FOR MIXING COLOURS.

The Spectroscope sorts out the above seven colours from sunlight (which is compounded of these seven colours). If painted in proper proportions on a wheel, as shown in the coloured illustration, and the wheel turned rapidly on a pivot through its centre, only a dull white will be perceived. If one colour be omitted, the result will be one colour—the result of the union of the remaining six.

What is reflected depends on the period of vibration of the electrons in the particular kind of matter. Generally, as the electrons receive the flood of billions of waves, they absorb either the long or the medium or the short, and they give us the wonderful colour-scheme of nature. In some cases the electrons continue to radiate long after the sunlight has ceased to fall upon them. We get from them "black" or invisible light, and we can take photographs by it. Other bodies, like glass, vibrate in unison with the period of the light-waves and let them stream through.

There are substances—"phosphorescent" things we call them—which give out a mysterious cold light of their own. It is one of the problems of science, and one of profound practical interest.

Light without Heat.

If we could produce light without heat our "gas bill" would shrink amazingly. So much energy is wasted in the production of heat-waves and ultra-violet waves which we do not want, that 90 per cent. or more of the power used in illumination is wasted. Would that the glow-worm, or even the dead herring, would yield us its secret! Phosphorus is the one thing we know as yet that suits the purpose, and—it smells! Indeed, our artificial light is not only extravagant in cost, but often poor in colour. The unwary person often buys a garment by artificial light, and is disgusted next morning to find in it a colour which is not wanted. The colour disclosed by the sun was not in the waves of the artificial light.

Beyond the waves of violet light are the still shorter and more rapid waves—the "ultra-violet" waves—which are precious to the photographer. As every amateur knows, his plate may safely be exposed to light that comes through a red or an orange screen. Such a screen means "no thoroughfare" for the blue and "beyond-blue" waves, and it is these which arrange the little grains of silver on the plate. It is the same waves which supply the energy to the little green grains of matter (chlorophyll) in the plant, preparing our food and timber for us, as will be seen later. The tree struggles upward and spreads out its leaves fanwise to the blue sky to receive them. In our coal-measures, the mighty dead forests of long ago, are vast stores of sunlight which we are prodigally using up.

The X-rays are the extreme end, the highest octave, of the series of waves. Their power of penetration implies that they are excessively minute, but even these have not held their secret from the modern physicist. From a series of beautiful experiments, in which they were made to pass amongst the atoms of a crystal, we learned their length. It is about the ten-millionth of a millimetre, and a millimetre is about the $\frac{1}{25}$ of an inch!

One of the most recent discoveries, made during a recent eclipse of the sun, is that light is subject to gravitation. A ray of light from a star is bent out of its straight path when it passes near the mass of the sun. Professor Eddington tells us that we have as much right to speak of a pound of light as of a pound of sugar. Professor Eddington even calculates that the earth receives 160 tons of light from the sun every year!

ENERGY: HOW ALL LIFE DEPENDS ON IT

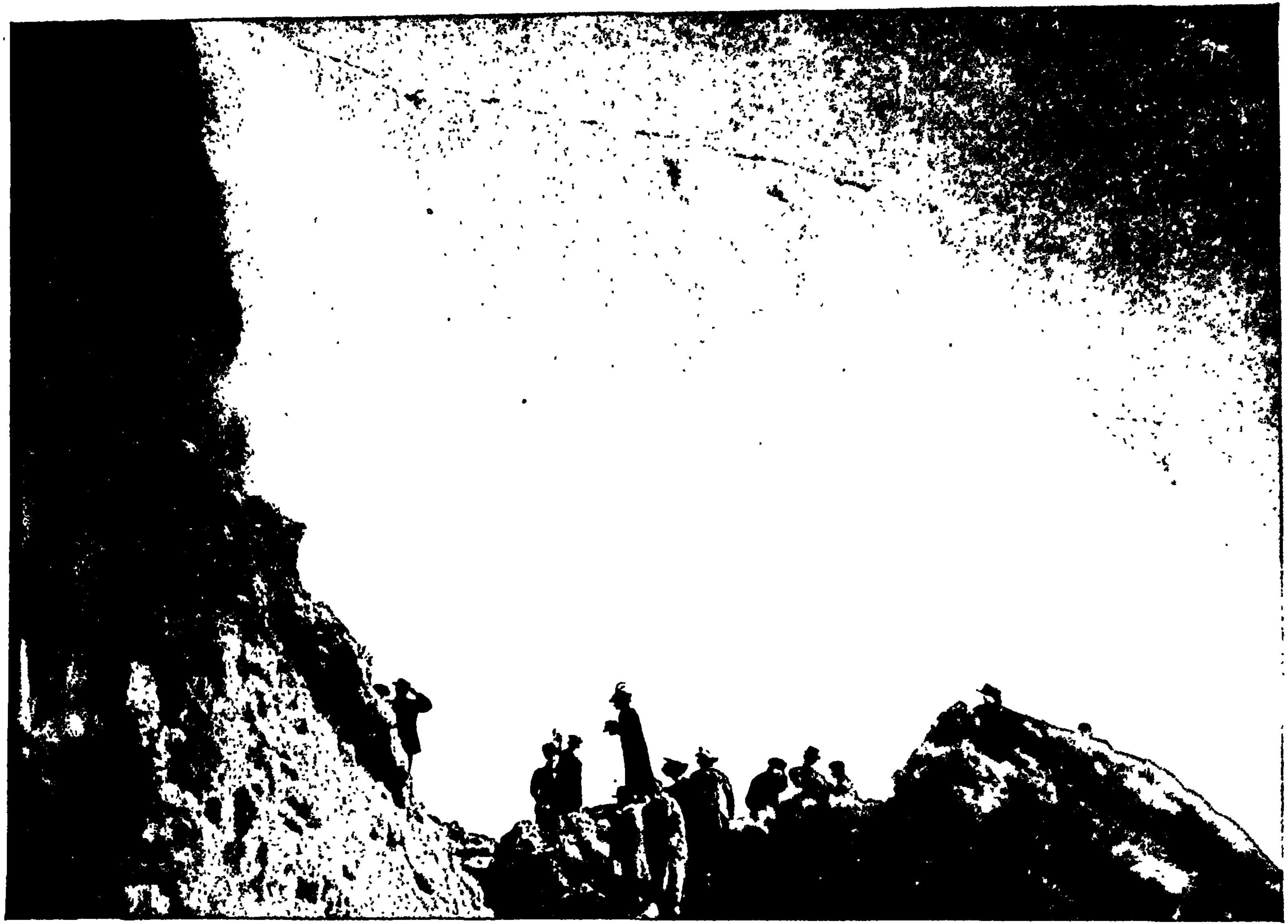
As we have seen in an earlier chapter, one of the fundamental entities of the universe is matter. A second, not less important, is called energy. Energy is indispensable if the world is to continue to exist, since all phenomena, including life, depend on it. Just as it is humanly impossible to create or to destroy a particle of matter, so is it impossible to create or to destroy energy. This statement will be more readily understood when we have considered what energy is.

Energy, like matter, is indestructible, and just as matter exists in various forms so does energy. And we may add, just as we are ignorant of what the negative and positive particles of electricity which constitute matter really are, so we are ignorant of the true nature of energy. At the same time, energy is not so completely mysterious as it once was. It is another of nature's mysteries which the advance of modern science has in some measure unveiled. It was only during the nineteenth century that energy came to be known as something as distinct and permanent as matter itself.

The existence of various forms of energy had been known, of course, for ages; there was the energy of a falling stone, the energy produced by burning wood or coal or any other substance, but the essential *identity* of all these forms of energy had not been suspected. The conception of energy as something which, like matter, was constant in amount, which could not be created nor destroyed, was one of the great scientific acquisitions of the past century.

Forms of Energy.

It is not possible to enter deeply into this subject here. It is sufficient if we briefly out-



NIAGARA FALLS.

The energy of this falling water is prodigious. It is used to generate thousands of horse power in great electrical installations The power is used to drive electric trams in cities 150 to 250 miles away.

line its salient aspects. Energy is recognised in two forms, kinetic and potential. The form of energy which is most apparent to us is the *energy of motion*; for example, a rolling stone, running water, a falling body, and so on. We call the energy of motion *kinetic energy*. Potential energy is the energy a body has in virtue of its position—it is its capacity, in other words, to acquire kinetic energy, as in the case of a stone resting on the edge of a cliff.

Energy may assume different forms; one kind of energy may be converted directly or indirectly into some other form. The energy of burning coal, for example, is converted into heat, and from heat energy we have mechanical energy, such as that manifested by the steam-engine. In this way we can transfer energy from one body to another. There is the energy of the great waterfalls of Niagara, for instance, which are used to supply the energy of huge electric power stations.

An important fact about energy is, that all energy *tends to take the form of heat energy*. The impact of a falling stone generates heat; a waterfall is hotter at the bottom than at the top—the falling particles of water, on striking the ground, generate heat; and most chemical changes are attended by heat changes. Energy may remain latent indefinitely in a lump of wood, but in combustion it is liberated, and we have heat as a result. The atom of radium or of any other radio-active substance, as it disintegrates, generates heat. "Every hour radium generates sufficient heat to raise the temperature of its own weight of water, from the freezing point to the boiling point." And what is heat? *Heat is molecular motion.* The molecules of every substance, as we have seen on a previous page, are in a state of continual motion, and the more vigorous the motion the hotter the body. As wood or coal burns, the invisible molecules of these substances are violently agitated, and give rise to ether waves which our senses interpret as light and heat. In this constant movement of the molecules, then, we have a manifestation of the energy of motion and of heat.

What Heat is.

That energy which disappears in one form reappears in another has been found to be universally true. It was Joule who, by churning water, first showed that a measurable quantity of mechanical energy could be transformed into a measurable quantity of heat energy. By causing an apparatus to stir water vigorously, that apparatus being driven by falling weights or a rotating flywheel or by any other mechanical means, the water became heated. A certain amount of mechanical energy had been used up and a certain amount of heat had appeared. The relation between these two things was found to be invariable. Every physical change in nature involves a transformation of energy, but the total quantity of energy in the universe remains unaltered. This is the great doctrine of the Conservation of Energy.

§ 13

Consider the source of nearly all the energy which is used in modern civilisation—coal. The great forests of the Carboniferous epoch now exist as beds of coal. By the burning of coal—a chemical transformation—the heat energy is produced on which at present our whole civilization depends. Whence is the energy locked up in the coal derived? From the sun. For millions of years the energy of the sun's rays had gone to form the vast vegetation of the Carboniferous era and had been transformed, by various subtle processes, into the potential energy that slumbers in those immense fossilized forests.

Substitutes for Coal.

The exhaustion of our coal deposits would mean, so far as our knowledge extends at present, the end of the world's civilisation. There are other known sources of energy, it is true. There is the energy of falling water; the great falls of Niagara are used to supply the energy of huge electric power stations. Perhaps, also, something could be done to utilise the energy of the tides—another instance of the energy of moving water. And attempts have been made to utilise directly the energy of the sun's rays. But all these sources of energy are small compared with the energy of coal. A suggestion was made at a recent British Association meeting that deep borings might be sunk in order to utilise the internal heat of the earth, but this is not, perhaps, a very practical proposal. By far the most effective substitutes for coal would be found in the interior

energy of the atom, a source of energy which, as we have seen, is practically illimitable. If the immense electrical energy in the interior of the atom can ever be liberated and controlled, then our steadily decreasing coal supply will no longer be the bugbear it now is to all thoughtful men.

The stored-up energy of the great coal-fields can be used up, but we cannot replace it or create fresh supplies. As we have seen, energy cannot be destroyed, but it can become *unavailable*. Let us consider what this important fact means.

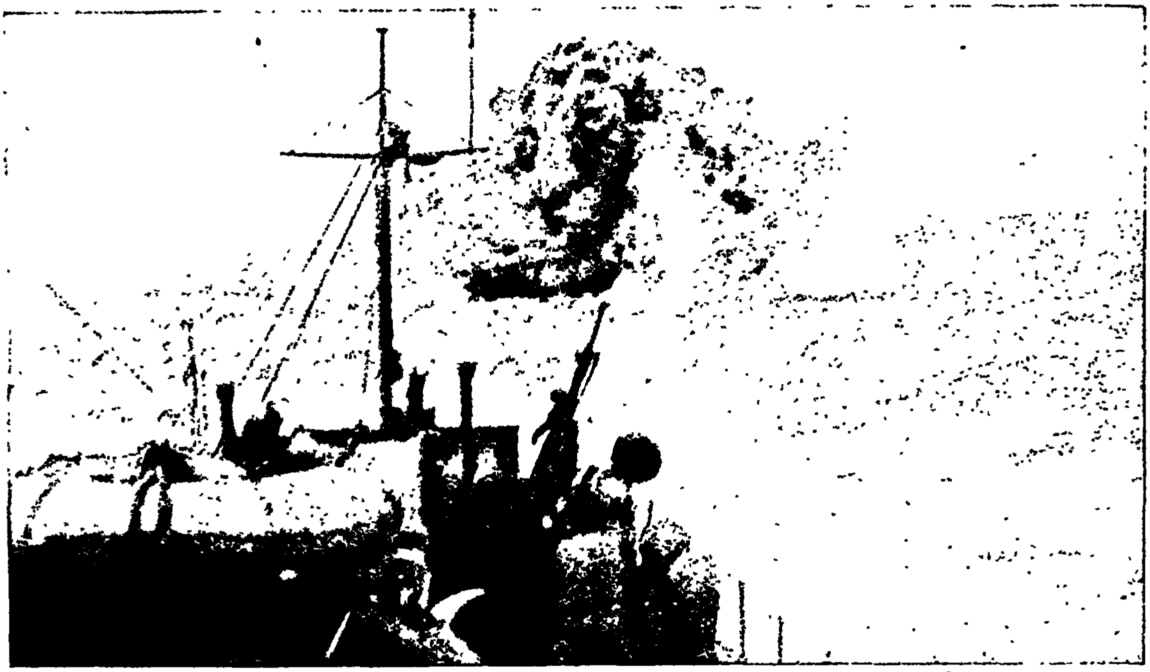


Photo: Stephen Cribb.

TRANSFORMATION OF ENERGY.

An illustration of Energy. The chemical energy brought into existence by firing the explosive manifesting itself as mechanical energy, sufficient to impart violent motion to tons of water.

§ 14

Dissipation of Energy.

Energy may become dissipated. Where does it go? since if it is indestructible it must still exist. It is easier to ask the question than to give a final answer, and it is not possible in this OUTLINE, where an advanced knowledge of physics is not assumed on the part of the reader, to go fully into the somewhat difficult theories put forward by physicists and chemists. We may raise the temperature, say, of iron, until it is white-hot. If we stop the process the temperature of the iron will gradually settle down to the temperature of surrounding bodies. As it does so, where does its previous energy go? In some measure it may pass to other bodies in contact with the piece of iron, but ultimately the heat becomes radiated away in space where we cannot follow it. It has been added to the vast reservoir of *unavailable* heat energy of uniform temperature. It is sufficient here to say that if all bodies had a uniform temperature we should experience no such thing as heat, because heat only travels from one body to another, having the effect of cooling the one and warming the other. In time the two bodies acquire the same temperature. The sum-total of the heat in any body is measured in terms of the kinetic energy of its moving molecules.

There must come a time, so far as we can see at present, when, even if all the heat energy of the universe is not radiated away into empty infinite space, yet a uniform temperature will prevail. If one body is hotter than another it radiates heat to that body until both are at the same temperature. Each body may still possess a considerable quantity of heat energy, which it has absorbed, but that energy, so far as reactions between those two bodies are con-

Photo: Underwood & Underwood.

"BOILING" A KETTLE ON ICE.

When a kettle containing liquid air is placed on ice it "boils," because the ice is intensely hot *when compared with the very low temperature of the liquid air.*

cerned, *is now unavailable.* The same principle applies whatever number of bodies we consider. Before heat energy can be utilised we must have bodies with different temperatures. If the whole universe were at some uniform temperature, then, although it might possess an enormous amount of heat energy, this energy would be unavailable.

What a Uniform Temperature would mean.

And what does this imply? It implies a great deal: for if all the energy in the world became unavailable, the universe, as it now is, would cease to be. It is possible that, by the constant interchange of heat radiations, the whole universe is tending to some uniform temperature, in which case, although all molecular motion would not have ceased, it would have become unavailable. In this sense it may be said that the universe is running down.

If all the molecules of a substance were brought to a standstill, that substance would be at the absolute zero of temperature. There could be nothing colder. The temperature at which all molecular motions would cease is known: it is $-273°$ C. No body could possibly attain a lower temperature than this: a lower temperature could not exist. Unless there exists in nature some process, of which we know nothing at present, whereby energy is renewed, our solar system must one day sink to this absolute zero of temperature. The sun, the earth, and every other body in the universe is steadily radiating heat, and this radiation cannot go on for ever, because heat continually tends to diffuse and to equalise temperatures.

But we can see, theoretically, that there is a way of evading this law. If the chaotic molecular motions which constitute heat could be *regulated*, then the heat energy of a body could be utilised directly. Some authorities think that some of the processes which go on in the living body do not involve any waste energy, that the chemical energy of food is transformed directly into work without any of it being dissipated as useless heat energy. It may be, therefore, that man will finally discover some way of escape from the natural law that, while energy cannot be destroyed, it has a tendency to become unavailable.

The primary reservoir of energy is the atom; it is the energy of the atom, the atom of elements in the sun, the stars, the earth, from which nature draws for all her supply of energy. Shall we ever discover how we can replenish the dwindling resources of energy, or find out how we can call into being the at present unavailable energy which is stored up in uniform temperature? "It looks as if our successors would witness an interesting race, between the progress of science on the one hand and the depletion of natural resources upon the other. The natural rate of flow of energy from its primary atomic reservoirs to the sea of waste heat energy of uniform temperature, allows life to proceed at a complete pace sternly regulated by the inexorable laws of supply and demand, which the biologists have recognised in their field as the struggle for existence." [1]

It is certain that energy is an actual entity just as much as matter, and that it cannot be created or destroyed. Matter and ether are receptacles or vehicles of energy. As we have said, what these entities really are in themselves we do not know. It may be that all forms of energy are in some fundamental way aspects of the same primary entity which constitutes matter: how all matter is constituted of particles of electricity we have already seen. The question to which we await an answer is: What is electricity?

§ 15

MATTER, ETHER, AND EINSTEIN

The supreme synthesis, the crown of all this progressive conquest of nature, would be to discover that the particles of positive and negative electricity, which make up the atoms of matter, are points or centres of disturbances of some kind in a universal ether, and that all our "energies" (light, magnetism, gravitation, etc.) are waves or strains of some kind set up in the ether by these clusters of electrons.

It is a fascinating, tantalising dream. Larmor suggested in 1900 that the electron is a tiny whirlpool, or "vortex," in ether; and, as such a vortex may turn in either of two opposite ways, we seem to see a possibility of explaining positive and negative electricity. But the difficulties have proved very serious, and the nature of the electron is unknown. A recent view is that it is "a ring of negative electricity rotating about its axis at a high speed," though that does not carry us very far. The unit of positive electricity is even less known. We must be content to know the general lines on which thought is moving toward the final unification.

We say "unification," but it would be a grave error to think that ether is the only possible basis for such unity, or to make it an essential part of one's philosophy of the universe. Ether was never more than an imagined entity to which we ascribed the most extraordinary properties, and which seemed then to promise considerable aid. It was conceived as an elastic solid of very great density, stretching from end to end of the universe, transmitting waves from star to star at the rate of 186,000 miles a second; yet it was believed that the most solid matter passed through it as if it did not exist.

Some years ago a delicate experiment was tried for the purpose of detecting the ether. Since the earth, in travelling round the sun, must move through the ether if the ether exists, there ought to be a stream of ether flowing through every laboratory; just as the motion of a ship through a still atmosphere will make "a wind." In 1887 Michelson and Morley tried to detect this. Theoretically, a ray of light in the direction of the stream ought to travel at a different rate from a ray of light against the stream or across it. They found no difference, and scores of other experiments have failed. This does not prove that there is no ether, as there is reason to suppose that our instruments would appear to shrink in precisely the same proportion as the alteration of the light; but the fact remains that we have no proof of the existence of ether. J. H. Jeans says that "nature acts as if no such thing existed." Even the phenomena of light and magnetism, he says, do not imply ether; and he thinks that the hypothesis may be abandoned. The primary reason, of course, for giving up the notion of the ether is that, as Einstein has shown, there is no way of detecting its existence. If there is an ether, then, since the earth is moving through it, there should be

[1] *Matter and Energy*, by Professor Soddy.

some way of detecting this motion. The experiment has been tried, as we have said, but, although the method used was very sensitive, no motion was discovered. It is Einstein who, by revolutionising our conceptions of space and time, showed that no such motion ever could be discovered, whatever means were employed, and that the usual notion of the ether must be abandoned. We shall explain this theory more fully in a later section.

INFLUENCE OF THE TIDES: ORIGIN OF THE MOON: THE EARTH SLOWING DOWN

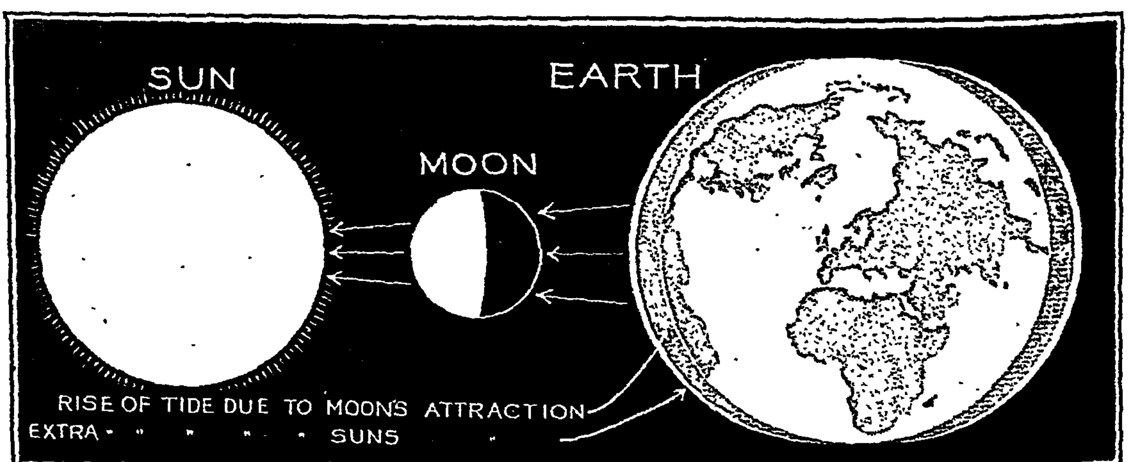
§ 16

Until comparatively recent times, until, in fact, the full dawn of modern science, the tides ranked amongst the greatest of nature's mysteries. And, indeed, what agency could be invoked to explain this mysteriously regular flux and reflux of the waters of the ocean? It is not surprising that that steady, rhythmical rise and fall suggested to some imaginative minds the breathing of a mighty animal. And even when man first became aware of the fact that this regular movement was somehow associated with the moon, was he much nearer an explanation? What bond could exist between the movements of that distant world and the diurnal variation of the waters of the earth? It is reported that an ancient astronomer, despairing of ever resolving the mystery, drowned himself in the sea.

But it was part of the merit of Newton's mighty theory of gravitation that it furnished an explanation even of this age-old mystery.

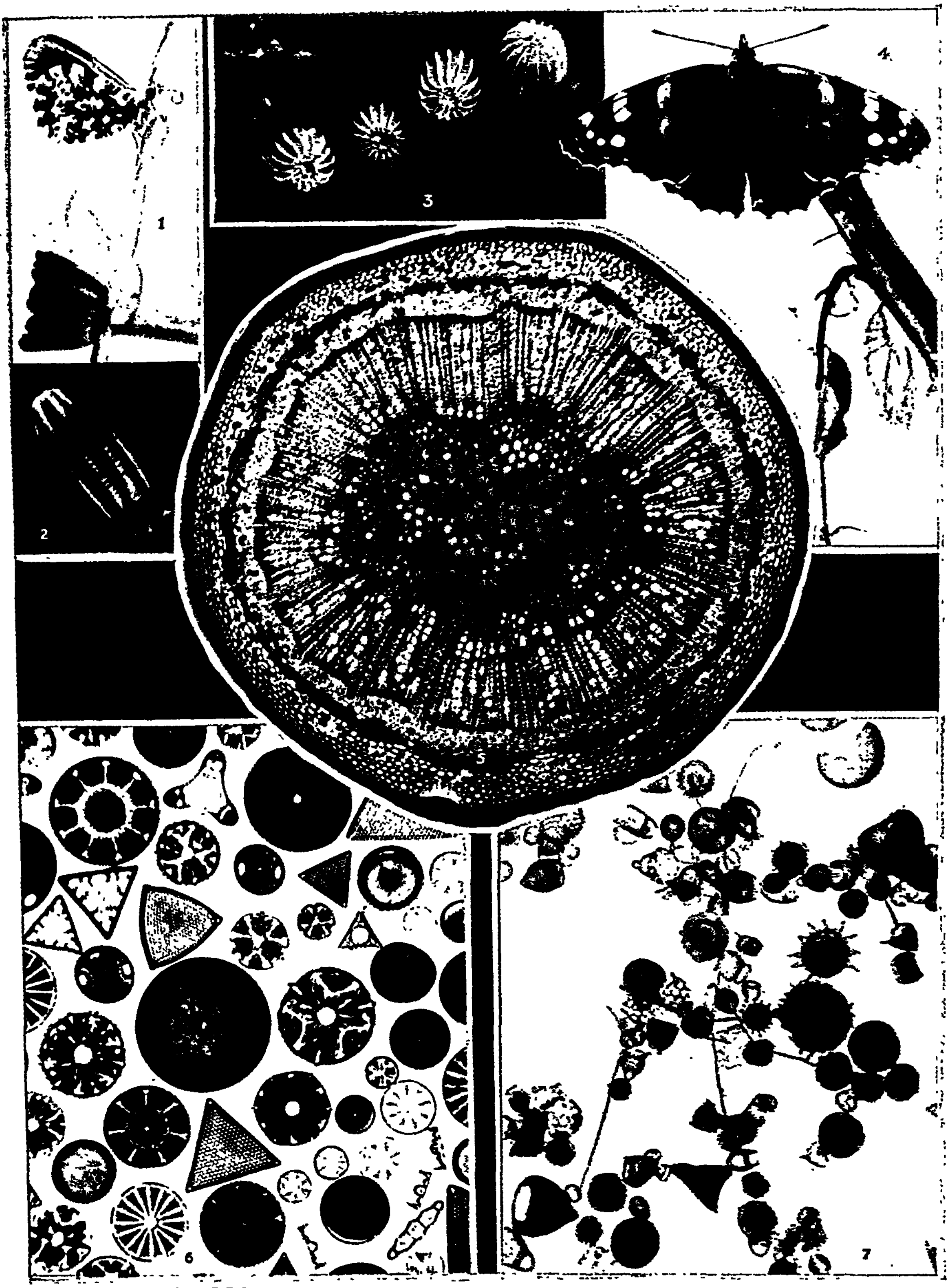
The Earth pulled by the Moon.

We can see, in broad outlines at any rate, that the theory of universal attraction can be applied to this case. For the moon, Newton taught us, pulls every particle of matter throughout the earth. If we imagine that part of the earth's surface which comprises the Pacific Ocean, for instance, to be turned towards the moon, we see that the moon's pull, *acting on the loose and mobile water*, would tend to heap it up into a sort of mound. The whole earth is pulled by the moon, but the water is more free to obey this pull than is the solid earth, although small tides are also caused in the earth's solid crust. It can be shown also that a corresponding hump would tend to be produced on the other side of the earth, owing, in this case, to the tendency of the water, being more loosely



THE CAUSE OF TIDES.

The tides of the sea are due to the pull of the moon, and, in lesser degree, of the sun. The whole earth is pulled by the moon, but the loose and mobile water is more free to obey this pull than is the solid earth, although small tides are also caused in the earth's solid crust. The effect which the tides have on slowing down the rotation of the earth is explained in the text.



Chromo-photos: J. J. Ward, F.E.S.

WONDERS OF THE MICROSCOPE

1. Male Orange-tip Butterfly (*Euchloe cardamines*) uncoiling its proboscis. 2. Egg of Orange-tip Butterfly, magnified 25 diameters. 3. Eggs of Painted Lady Butterfly, magnified 25 diameters. 4. Painted Lady Butterfly (*Pyrameis cardui*), just emerged from its chrysalis; the broken pupa skin is seen beneath. 5. Transverse section of young twig of Beech (*Fagus sylvatica*) with tissues artificially stained to aid in their identification, e.g. innermost the pith (green), the wood (blue), magnified 40 diameters. 6. Siliceous shells which enclose the microscopic plants called Diatoms, magnified 100 diameters. 7. Siliceous skeletons of the unicellular animals known as Radiolaria, magnified 100 diameters.

connected, to lag behind the solid earth. If the earth's surface were entirely fluid the rotation of the earth would give the impression that these two humps were continually travelling round the world, once every day. At any given part of the earth's surface, therefore, there would be two humps daily, i.e. two periods of high water. Such is the simplest possible outline of the gravitational theory of the tides.

The actually observed phenomena are vastly more complicated, and the complete theory bears very little resemblance to the simple form we have just outlined. Everyone who lives in the neighbourhood of a port knows, for instance, that high water seldom coincides with the time when the moon crosses the meridian. It may be several hours early or late. High water at London Bridge, for instance, occurs about one and a half hours after the moon has passed the meridian, while at Dublin high water occurs about one and a half hours before the moon crosses the meridian. The actually observed phenomena, then, are far from simple; they have, nevertheless, been very completely worked out, and the times of high water for every port in the world can now be prophesied for a considerable time ahead.

It would be beyond our scope to attempt to explain the complete theory, but we may mention one obvious factor which must be taken into account. Since the moon, by its gravitational attraction, produces tides, we should expect that the sun, whose gravitational attraction is so much stronger, should also produce tides and, we would suppose at first sight, more powerful tides than the moon. But while it is true that the sun produces tides, it is not true that they are more powerful than those produced by the moon. The sun's tide-producing

The Action of Sun and Moon.

Photo: G. Brocklehurst.

THE AEGIR ON THE TRENT.

An exceptionally smooth formation due to perfect weather conditions. The wall-like formation of these tidal waves (see also page 219) will be noticed. The reason for this is that the downward current in the river heads the sea-water back, and thus helps to exaggerate the advancing slope of the wave. The exceptional spring tides are caused by the combined operation of the moon and the sun, as is explained in the text.

power is, as a matter of fact, less than half that of the moon. The reason of this is that *distance* plays an enormous rôle in the production of tides. The mass of the sun is 26,000,000 times that of the moon; on the other hand it is 386 times as far off as the moon. This greater distance more than counterbalances its greater mass, and the result, as we have said, is that the moon is more than twice as powerful. Sometimes the sun and moon act together, and we have what are called spring tides; sometimes they act against one another, and we have neap tides. These effects are further complicated by a number of other factors, and the tides, at various places, vary enormously. Thus at St. Helena the sea rises and falls about three feet, whereas in the Bay of Fundy it rises and talls more than fifty feet. But here, again, the reasons are complicated.

§ 17

Origin of the Moon.

But there is another aspect of the tides which is of vastly greater interest and importance than the theory we have just been discussing. In the hands of Sir George H. Darwin, the son of Charles Darwin, the tides had been made to throw light on the evolution of our solar system. In particular, they have illustrated the origin and development of the system formed by our earth and moon. It is quite certain that, long ages ago, the earth was rotating immensely faster than it is now, and that the moon was so near as to be actually in contact with the earth. In that remote age the moon was just on the point of separating from the earth, of being thrown off by the earth. Earth and moon were once one body, but the high rate of rotation caused this body to split up into two pieces; one piece became the earth we now know, and the other became the moon. Such is the conclusion to which we are led by an examination of the tides. In the first place let us consider the energy produced by the tides. We see evidences of this energy all round the world's coastlines. Estuaries are scooped out, great rocks are gradually reduced to rubble, innumerable tons of matter are continually being set in movement. Whence is this energy derived? Energy, like matter, cannot be created from nothing; what, then, is the source which makes this colossal expenditure possible.

The answer is simple, but startling. *The source of tidal energy is the rotation of the earth.*

The Earth slowing down.

The massive bulk of the earth, turning every twenty-four hours on its axis, is like a gigantic flywheel. In virtue of its rotation it possesses an enormous store of energy. But even the heaviest and swiftest flywheel, if it is doing work, or even if it is only working against the friction of its bearings, cannot dispense energy for ever. It must, gradually, slow down. There is no escape from this reasoning. It is the rotation of the earth which supplies the energy of the tides, and, as a consequence, the tides must be slowing down the earth. The tides act as a kind of brake on the earth's rotation. These masses of water, *held back by the moon*, exert a kind of dragging effect on the rotating earth. Doubtless this effect, measured by our ordinary standards, is very small; it is, however, continuous, and in the course of the millions of years dealt with in astronomy, this small but constant effect may produce very considerable results.

But there is another effect which can be shown to be a necessary mathematical consequence of tidal action. It is the moon's action on the earth which produces the tides, but they also react on the moon. The tides are slowing down the earth, and they are also driving the moon farther and farther away. This result, strange as it may seem, does not permit of doubt, for it is the result of an indubitable dynamical principle, which cannot be made clear without a mathematical discussion. Some interesting consequences follow.

Since the earth is slowing down, it follows that it was once rotating faster. There was a period, a long time ago, when the day comprised only twenty hours. Going farther back still we come to a day of ten hours, until, inconceivable ages ago, the earth must have been rotating on its axis in a period of from three to four hours.

At this point let us stop and inquire what was happening to the moon. We have seen that at present the moon is getting farther and farther away. It follows, therefore, that when the day was shorter the moon was

nearer. As we go farther back in time we find the moon nearer and nearer to an earth rotating faster and faster. When we reach the period we have already mentioned, the period when the earth completed a revolution in three or four hours, we find that the moon was so near as to be almost grazing the earth. This fact is very remarkable. Everybody knows that there is a *critical velocity* for a rotating flywheel, a velocity beyond which the flywheel would fly into pieces, because the centrifugal force developed is so great as to overcome the cohesion of the molecules of the flywheel. We have already likened our earth to a flywheel, and we have traced its history back to the point where it was rotating with immense velocity. We have also seen that, at that moment, the moon was barely separated from the earth. The conclusion is irresistible. In an age more remote the earth *did* fly in pieces, and one of those pieces is the moon. Such, in brief outline, is the tidal theory of the origin of the earth-moon system.

The Day becoming longer.

At the beginning, when the moon split off from the earth, it obviously must have shared the earth's rotation. It flew round the earth in the same time that the earth rotated, that is to say, the month and the day were of equal length. As the moon began to get farther from the earth, the month, because the moon took longer to rotate round the earth, began to get correspondingly longer. The day also became longer, because the earth was slowing down, taking longer to rotate on its axis, but the month increased at a greater rate than the day. Presently the month became equal to two days, then to three, and so on. It has been calculated that this process went on until there were twenty-nine days in the month. After that the number of days in the month began to decrease until it reached its present value or magnitude, and will continue to decrease until once more the month and the day are equal. In that age the earth will be rotating very slowly. The braking action of the tides will cause the

Photo: G. Brocklehurst.

A BIG SPRING TIDE, THE AEGIR ON THE TRENT.

earth always to keep the same face to the moon; it will rotate on its axis in the same time that the moon turns round the earth. If nothing but the earth and moon were involved this state of affairs would be final. But there is also the effect of the solar tides to be considered. The moon makes the day equal to the month, but the sun has a tendency, by still further slowing down the earth's rotation on its axis, to make the day equal to the year. It would do this, of course, by making the earth take as long to turn on its axis as to go round the sun. It cannot succeed in this, owing to the action of the moon, but it can succeed in making the day rather longer than the month.

Surprising as it may seem, we already have an illustration of this possibility in the satellites of Mars. The Martian day is about one half-hour longer than ours, but when the two minute satellites of Mars were discovered it was noticed that the inner one of the two revolved round Mars in about seven hours forty minutes. In one Martian day, therefore, one of the moons of Mars makes more than three complete revolutions round that planet, so that, to an inhabitant of Mars, there would be more than three months in a day.

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IX

THE WONDERS OF MICROSCOPY

THE use of a lens for magnifying purposes is ancient, but the first "compound microscope" was probably made in 1590 by a Dutchman, Zacharias Jansen, whose invention was followed up by Galileo a few years later. But it did not become an effective instrument till towards the middle of the eighteenth century. In a "simple" microscope we look at the object directly through a lens or through several lenses. This kind of instrument is often used for microscopic dissection. But in the "compound" microscope we look through an eye-lens or ocular at an inverted image of the object formed inside the tube of the instrument by an object-lens or objective. In all ordinary microscopes there are two lenses in the eye-piece and three lenses in the objective, and all sorts of ingenious devices have been invented for making the most of the magnifying power without losing clearness and definition.

In the early days of microscopy the instrument was to a large extent a scientific toy. The observers magnified objects and often drew them very beautifully, but without making them more intelligible. There is not much gain in seeing a minute object loom large unless we understand it better. This was a necessary stage. Soon, however, great steps were taken, and one of these may be called *the discovery of the invisible world of life.* The pioneer explorer was surely the Dutch observer Leeuwenhoek (1632–1723), who discovered minute creatures like the Rotifers or Wheel-Animalcules which are com-

An Invisible World of Life.

Photo: J. J. Ward.

FULL-FACE PORTRAIT OF THE COMMON WASP.

The large compound eyes are well seen, and above these are the feelers or antennæ. Protruding underneath the front of the head are some of the biting mouth-parts, and the first pair of legs are also seen. Note also the numerous setæ or bristles.

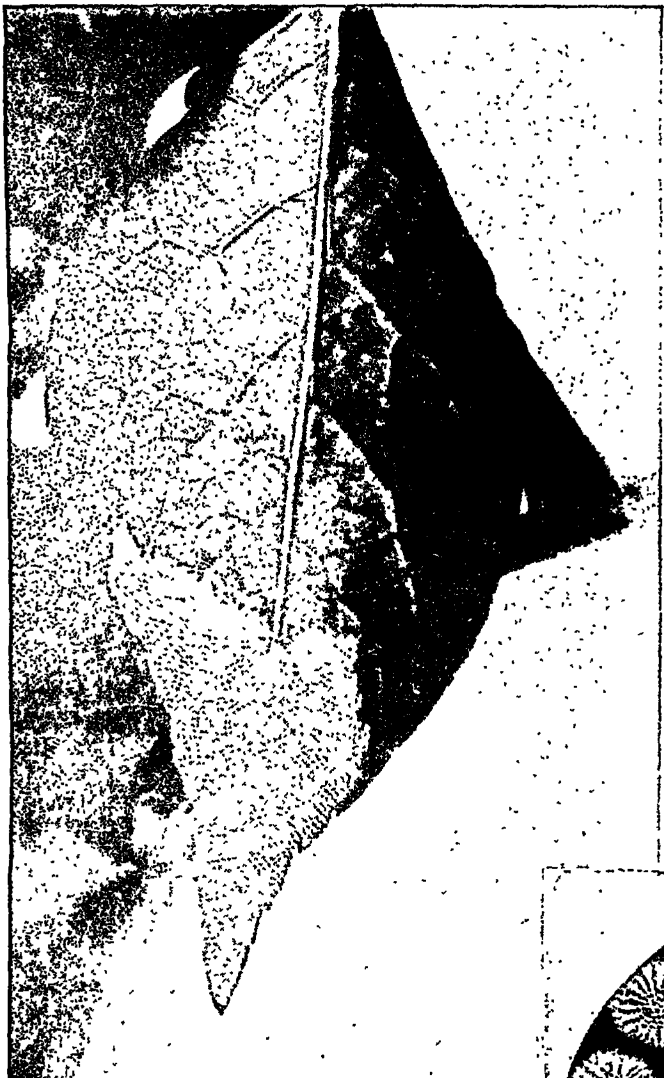


Photo: J. J. Ward.

EGGS OF THE BROAD-BORDERED UNDERWING MOTH, CROWDED TOGETHER ON THE UNDERSIDE OF THE LEAF.

There are about 1,300 eggs, all deposited in one evening. In another photograph a few of the eggs are shown much enlarged.

mon in ponds, and the Infusorians which abound wherever vegetable matter rots away in water. He made numerous microscopes, and though they had neither tube nor mirror, they were sufficient to enable him to demonstrate his animalcules before the Royal Society of London, the Fellows signing an affidavit that they had seen the little creatures. It was Leeuwenhoek also who (in 1687) discovered bacteria, the very minute organisms which cause all putrefaction, are responsible for bringing about many diseases, and are yet of immense service to many living creatures.

It was not till long afterwards that Pasteur and others demonstrated the importance of bacteria, but it was a great event in the history of science when Leeuwenhoek first proved their presence. It was literally the discovery of a new world with a teeming population, with incalculable powers for good and evil. It must have been a seed in the human mind, this idea of an intense activity going on all unseen until men stuck lenses of glass in front of their own.

Another great event, though its importance was not recognised till afterwards, was *the discovery of the male elements* or spermatozoa of animals, which fertilise the egg-cells so that these may begin to develop. This discovery was probably due (1677) to a medical student in Leyden, Louis de Hamen, who showed them to

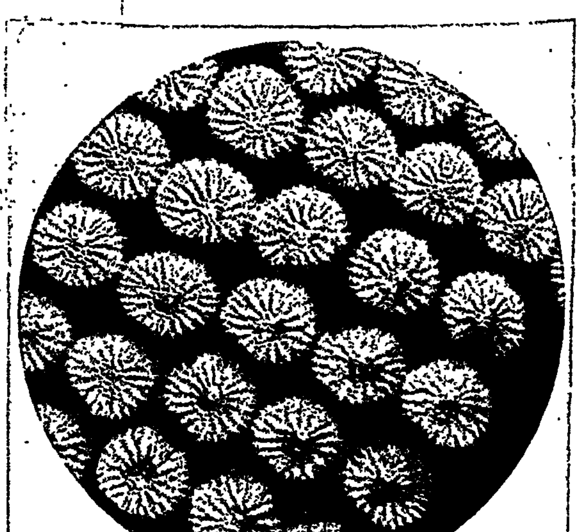


Photo: J. J. Ward.

EGGS OF THE BROAD-BORDERED UNDERWING MOTH.

Each egg has a shell of the substance called chitin, which covers the living skin of all insects. The egg-shell is secreted in the oviduct of the female insect. Its outer surface is very beautifully sculptured, but the significance of the pattern is unknown. It looks as if the beauty of many organic structures is like that of snow crystals—an expression of the way in which the dance of molecules sinks into relative rest.

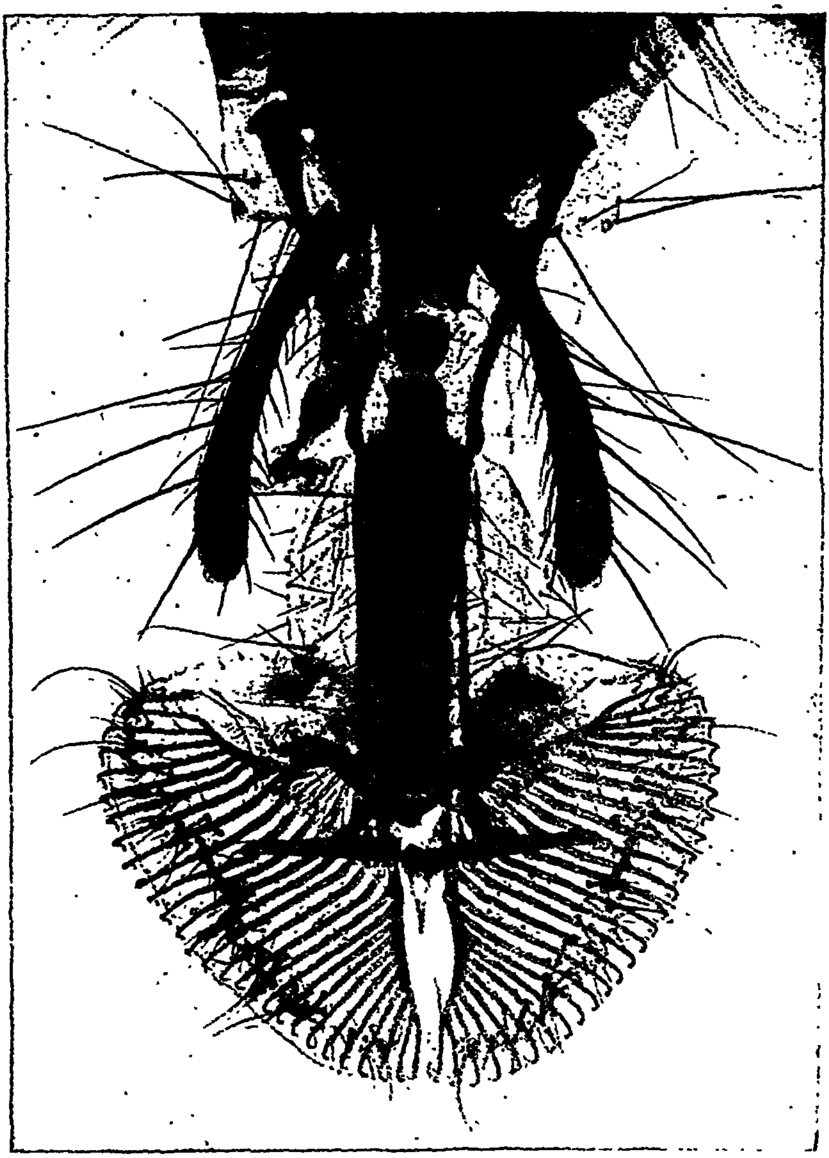


Photo. J. J. Ward.

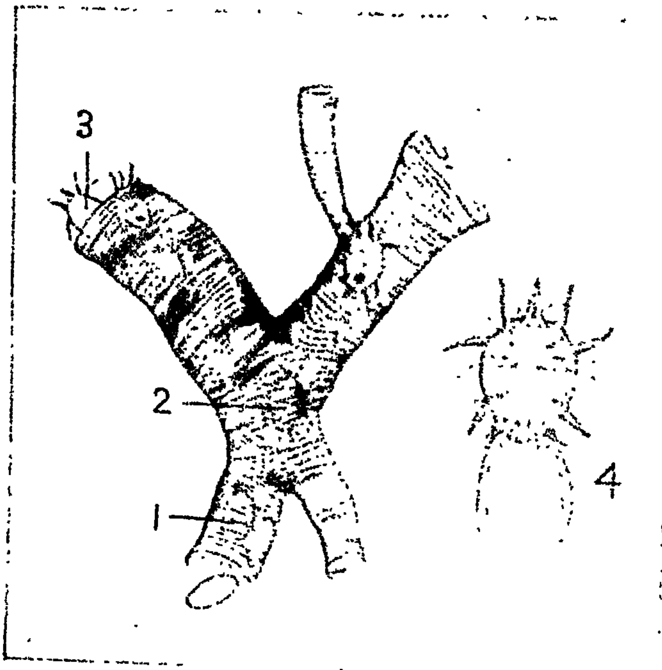
THE PROBOSCIS OF A HOUSE-FLY.

It is a tubular structure ending in two broad pads, traversed by numerous small canals by which saliva from the mouth can be passed out on the surface of the pads. This juice dissolves solid substances like sugar, and the result is sucked up the proboscis. Two unjointed sensitive palps are also shown. When not in use the proboscis is drawn into a hollow beneath the fly's head.

Leeuwenhoek, but it was not till more than a hundred years later that the meaning of these sperm-cells was recognised. And it is interesting to remember that it was not till 1843 that another medical student, Martin Barry, in Edinburgh, observed for the first time in the rabbit the fertilisation of the mammalian ovum by the spermatozoon. In modern times an extraordinary intensity of research has been focused on the usually microscopic egg-cell and the always microscopic sperm-cell. In the union of these an individual animal has its beginning and it is interesting to trace this modern study, so important in connection with heredity, back and back to the Leyden student's first glimpse of spermatozöa.

But we must not lose the wood in the trees: one of the real wonders of microscopy, rising high above any mere curiosity collecting, is the discovery of a world of invisible life. There are the bacteria, which may be regarded as the simplest of living creatures; there are the

yeasts and the simple moulds; there are the single-celled green plants which play so important a rôle in the economy of the sea by providing food for humble animals like water-fleas. There are the one-celled animals or Protozoa, such as the chalk-forming Foraminifera, the Infusorians which often serve as middlemen between the products of bacterial putrefaction and some higher incarnation in crustacean or worm, and the death-bringing organisms of malaria and sleeping-sickness. There are also many-celled animals of microscopic dimensions, such as the wheel-animalcules of the pond and the minute crustaceans which play so important a part in the circulation of matter by feeding on the microscopic Algæ and Infusorians in the water and being themselves devoured by fishes. There are also the invisible early stages of many important parasites, whose life-history would have remained quite obscure if naturalists had been without microscopes. It seems hardly too much to say that the system of animate nature would be uncomfortably magical if the microscope had not enabled us to detect the missing links in many a chain of events. The liver-fluke which often destroys the farmer's sheep is a relatively large animal—about an inch long—but it starts its life as a microscopic egg which develops into a microscopic larva that enters a water-snail, and has a remarkable history there. The tapeworm with which man becomes infected by eating bad beef imperfectly cooked, may be several yards in length, but it began as a microscopic egg which was swallowed by a bullock and hatched into a microscopic boring larva, which eventually became the beef-bladderworm. In hundreds of cases the microscope reveals the life-history. In the course of a few years a very serious bee-pest, known as Isle of Wight disease, has spread throughout Britain, causing havoc among the hives, and greatly discouraging a lucrative and wholesome industry. The nature and meaning of this disease remained baffling until strenuous and patient microscopic work by Rennie and White demonstrated that the plague was bound up with the presence of an extremely minute mite in the anterior breathing-tubes of the bee. And when the cause of a disease is discovered, it is not usually long before investigation also reveals a cure.



"ISLE OF WIGHT DISEASE" HAS SPREAD ALL OVER BRITAIN, CAUSING THE RUIN OF THOUSANDS OF BEEHIVES.

It is associated with the presence of a very minute mite (*Tarsonemus woodi*) in certain air tubes or tracheæ of the bee. The figure shows an enlargement of a branching air-tube with a mite's egg (1), an immature female (2), a mature female (3) struggling out. In Fig. 4 is shown a mature mite still more enlarged: note the four pairs of walking legs with bristles and two pairs of piercing and sucking mouth parts. The mite feeds on the bee's blood, and as the numbers increase the infected air-tubes become blocked. This means that certain muscles, e.g. those of flight, are bereft of their normal supply of oxygen and naturally go out of gear. The bees are unable to fly, and crawl about helplessly in front of the hive.

Intricacy of Architecture in Small Animals.

Long before there was any microscope the use of the scalpel, helped sometimes by the simple lens, had revealed the intricacies of the body in man and in animals. We may save ourselves from exaggerating modern achievements by recalling how much Aristotle (384–322 B.C.) knew of animal structure. He dissected many a creature, such as the sea-urchin; he saw the beating of the tiny heart of the unhatched chick; he described how the embryo of the smooth dogfish is bound to the wall of its mother's

Photo: J. J. Ward.

FOOT OF SPIDER, SHOWING COMBED CLAWS AND CUTTING-HOOK BELOW.

When the spider runs up a wall or creeps along a ceiling, it is gripping the roughnesses on the surface by means of these combed claws. There is mention in the Scriptures of the spider "laying hold with her hands"; but some scholars say that the Hebrew word really refers to the wall-lizard called the Gecko, which has toes with adhesive surfaces. A spider cannot climb up a quartz fibre, for its claws will not grip the smooth surface.

oviduct, and much more besides. And Aristotle had his successors, few and far between, who kept up the anatomising tradition, long before there was any microscope. But what the early microscopists did was to reveal the fact that the multitude of minute creatures which it was hopeless to try to dissect had an intricacy of structure comparable to that in larger and higher animals. One of the pioneers in this exploration was the Italian, Marcello Malpighi (1628–1694), who described the internal architecture of the silkworm as animal had never been described before. He worked so hard that he threw himself into a fever and set up inflammation in his eyes. "Nevertheless, in performing these researches so many marvels of nature were spread before my eyes that I experienced an internal pleasure that my pen could not describe." He discovered, for instance, the delicate branching air-tubes (or tracheæ) which carry air to every hole and corner of the insect's body; and it is plain from this instance that he discovered internal structures which made the insect at once more intelligible. This sort of discovery (we still call the excretory organs of insects Malpighian tubes) was characteristic of the man, and characteristic of a kind of investigation which continues untiringly to the present day. It makes for a realisation of the unity of organic nature to disclose in creatures which will pass through the eye of a needle the presence of organs comparable to those in man himself. Much of Malpighi's work was done with a simple lens, but he had also his microscope with two lenses, and in any case his name may be associated with the great discovery that as far as intricacy of structure goes, size does not count for much.

It is a very striking experience to observe a

Photo: J. J. Ward.

FOOT OF A WINGLESS FLY, *MELOPHAGUS OVINUS*, OFTEN, BUT BADLY, NAMED THE SHEEP-TICK.

For a tick is not an insect at all. The "ked," as it is popularly called, has a compressed body about a quarter of an inch long. It has piercing mouth-parts and sucks blood from the sheep. Very striking are the two curved claws at the tip of the foot, well suited for holding on to the fleece. Part of the body, with short hairs, is also shown. The "keds" usually pass from one sheep to another by contact.

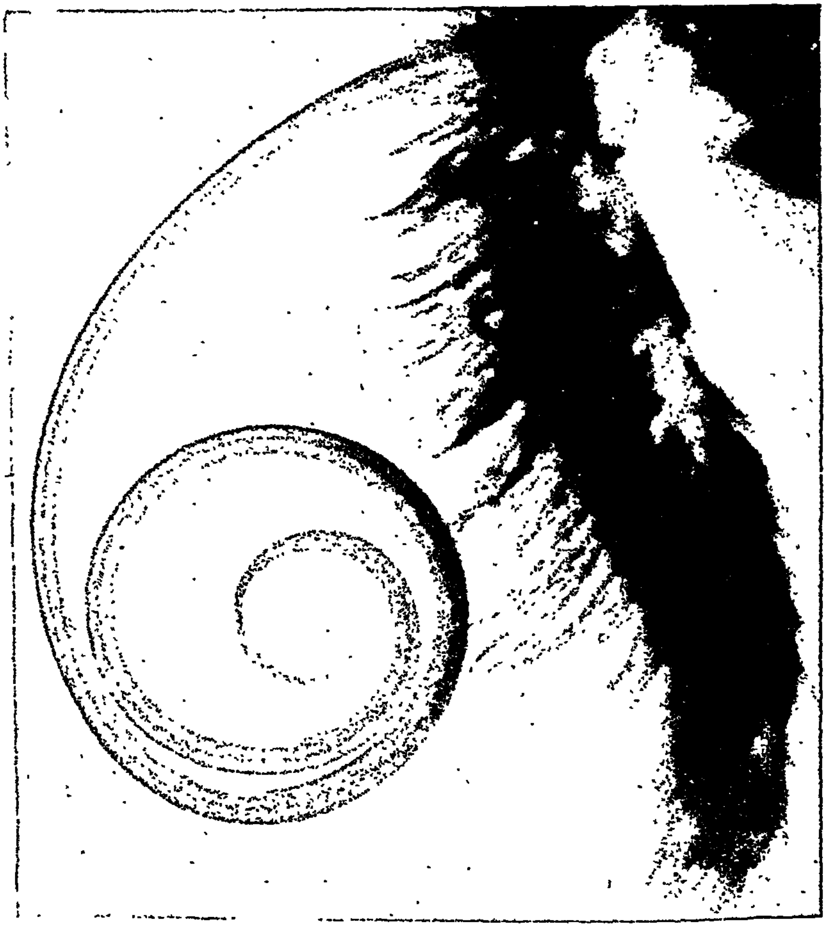


Photo: J. J. Ward.

COILED PROBOSCIS OF A BUTTERFLY.

It is a paired structure, but only one-half of the tube is shown. It is used for sucking up nectar from flowers, the suction being due to a muscular pump inside the insect's head. In some of the Hawk Moths the proboscis may be 10 inches long. Rising from near the base of the proboscis there are two palps covered with sensitive hairs, as the photograph shows. The caterpillar or larva of the butterfly has biting mouth-parts in great contrast to the suctorial parts of the adult.

minute animal like the Rotifer Hydatina, no more than a pin-prick in size, and to find that it has a food-canal, a chewing apparatus, a nerve-centre, various muscles, a delicate kidney-tube, and so on. Yet it is such a pigmy when all is said. There are little beetles (Trichopterygids), well represented in Britain, which are sometimes only one-hundredth of an inch in length—practically invisible. Yet within that small compass there is the same kind of intricacy that is found in a Goliath Beetle—brain and nerves, muscles and food-canal, air-tubes and kidney-tubes, blood and germ-cells. He would be a bold man who says he quite understands how there is all this intricacy within bulk so small. But this we venture to call the second wonder of microscopy, that *great intricacy of structure may occur in a microscopically minute living body*.

Intricacy of Vital Architecture.

We have singled out the name of Malpighi in Italy as a pioneer in the exploration of the structure of minute animals, but we might have taken with equal justice Swammerdam in Holland, whose precision of minutiose observation has rarely been equalled. He is memorable not only for his anatomy of small creatures, but, like Malpighi, for his minute anatomy of larger ones, and here we might also include the early British microscopists, Hooke and Grew. For this was another line of advance, to disclose the intricacy of vital

architecture that lay beyond the limits of scalpel and simple lens. Thus it was a great step when Swammerdam discovered in 1658 the blood corpuscles of the frog; when Malpighi demonstrated the air-cells in the lung where the gaseous interchange takes place between blood and air; when Leeuwenhoek completed Harvey's theory of the circulation of the blood by demonstrating in 1680 the capillary connection between arteries and veins. Speaking of the tail of the tadpole, he said, " A sight presented itself more delightful than any mine eyes had ever beheld; for here I discovered more than fifty circulations of the blood in different places, while the animal lay quiet in the water, and I could bring it before my microscope to my wish. For I saw not only that in many places the blood was conveyed through exceedingly minute vessels, from the middle of the tail toward the edges, but that each of the vessels had a curve or turning, and carried the blood back toward the middle of the tail, in order to be again conveyed to the heart." Such was the momentous observation of the fact that the arteries leading *from* the heart, and the veins leading *back to* the heart are bound into one system by the intermediation of the capillaries.

This is an easy illustration of the kind of service microscopy has never ceased to render—making vital activity more intelligible by revealing the intricacy of structure. For it is in a study of the structure that we get a better understanding of the ways and means of life. It is not the whole story of the workshop to know the furnishings and the tools, but it is an essential part of the story. We hastily draw away our finger from a hot plate—a reflex action—it is only with the help of the microscope that the physiologist can tell how the message travels by sensory nerve-cells to intermediary nerve-cells and thence to motor nerve-cells which command the muscles to move. Our mouth waters at the sight of palatable food: it is only by help of the microscope that the physiologist is able to trace the message from eye to salivary glands, and to show how in the cells or unit-corpuscles of these glands there is a preparation of secretion which is discharged when the trigger is pulled by a nervous command. The study of vital activity requires experiment and chemical analysis, but it cannot dispense with the microscope. So we venture to say that a third wonder of microscopy is the revelation of *the intricacy of minute structure.*

The Stones and Mortar of the House of Life.

It is a long and tangled story which tells of the gradual discovery of the cells or unit-areas of which all but the simplest living creatures are built up, and of the living matter or protoplasm which these cells contain or portion off. The genius of the short-lived French anatomist

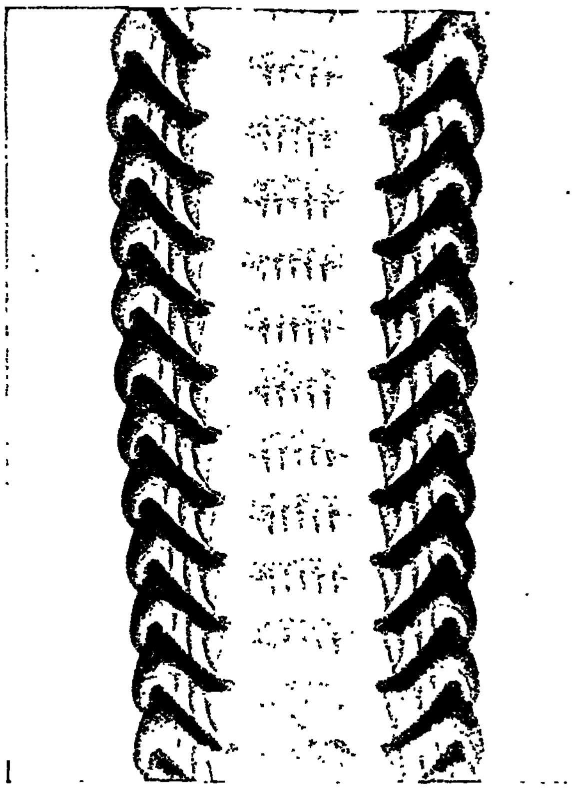


Photo: J. J. Ward.

RASPING RIBBON OR FILE, BADLY CALLED THE PALATE, IN THE MOUTH OF THE WHELK.

By means of this toothed flexible file the whelk can bore a hole through the skin, or even through the shell, of an animal on which it preys.

Bichât had analysed a living body into a web of tissues—nervous, muscular, glandular, connective, and epithelial. But to Schwann and Schleiden, Virchow and Goodsir, is due the credit of a further advance—the Cell-Theory—certainly one of the triumphs of microscopes with brains behind them. The Cell-Theory or Cell-Doctrine states three facts. (1) that all plants and animals have a cellular structure (being either single cells or combinations of

numerous cells); (2) that every living creature reproduced in the ordinary way, begins its life as a single cell, and, if it does not remain at that humble level, proceeds to build up a body by the division and re-division of cells which eventually form tissues and organs; and (3) that the activities of a many-celled organism are the co-ordinated summation of the activities of the component cells. "Every animal," Virchow said, "appears as a sum of vital units." Not that we are to think of an ordinary animal as a colony of cells, as a mob is a collection of angry men, or even as a battalion is a co-ordination of disciplined soldiers. It is nearer the truth to think of the fertilised egg-cell—a *potential organism,* when we come to think of it—dividing and re-dividing into cells so that the unified business of life may be more effectively carried on by division of labour. As one of the greatest of botanists said: It is not that the cells form the plant; it is rather that the plant makes the cells.

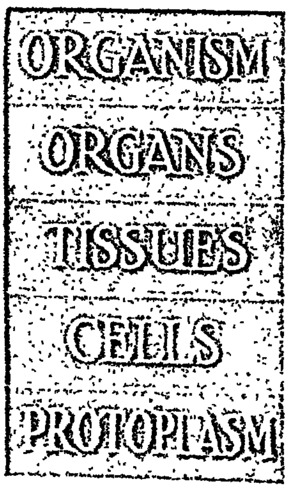
JOHN GOODSIR, 1814–1867, PROFESSOR OF ANATOMY IN THE UNIVERSITY OF EDINBURGH.

A remarkable pioneer who had an important share, along with Schwann, Schleiden, and Virchow, in establishing the Cell-Theory—one of the foundation-stones of Biology.

With a few exceptions, notably Aristotle, the early naturalists were content to study the outsides of animals; then came the study of internal organs, like hearts and lungs; Bichât marks the deeper penetration to the tissues that make up the organs; then came the recognition of the cells that compose the tissues; finally there was the recognition of protoplasm—which Huxley called "the physical basis of life." It may be useful to place the different levels of study in a clear scheme (see illustration opposite).

The Microcosm of the Cell.

The old picture of a cell was that of a little drop of living matter with a kernel or nucleus, and sometimes with an enclosing wall. But the revelations of the microscope have made this picture obsolete. We have to think of a more or less unified minute area of great chemical diversity, with complex particles and unmixing droplets restlessly moving in a fluid. In the centre of this whirlpool, with its flotsam of reserve-products and waste-products, there floats the nucleus, a little world in itself. Inside its membrane, through which materials are ever permeating out and in, there are readily stainable nuclear bodies or "chromosomes," usually a definite number for each species. And each "chromosome" is built up of bead-like "microsomes" strung on a transparent ribbon. It



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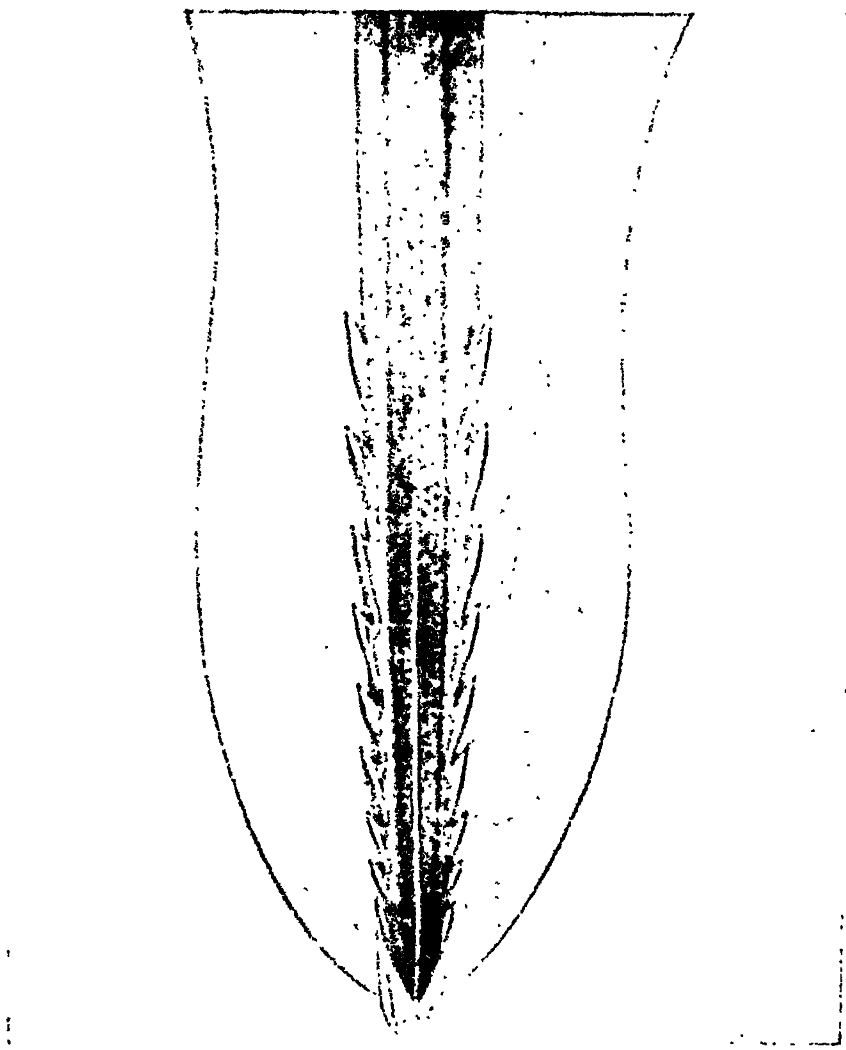


Photo: James's Press Agency.

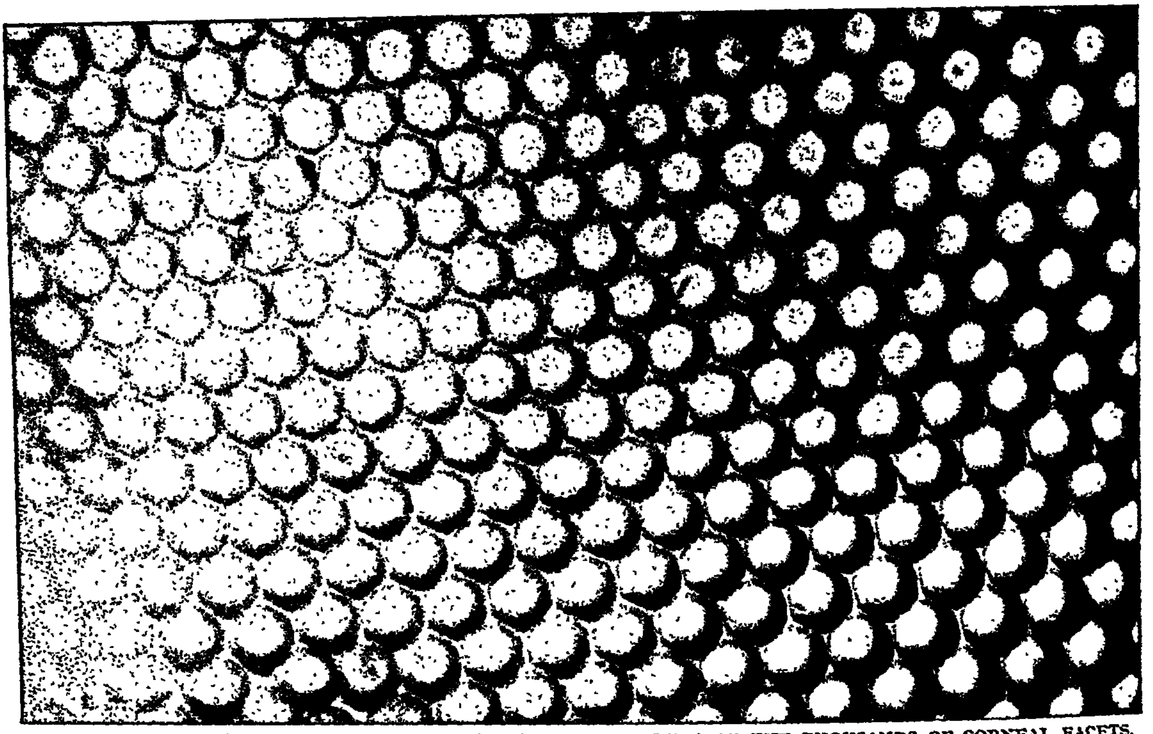
STING OF THE HONEY BEE.

In the middle there is a deeply grooved "guide," pointed and barbed at the tip. Working in a concavity on each side of the "guide," is a slender lancet or "dart," with recurved barbs at the tip. There are bevellings which keep the darts sliding smoothly along the guide. The tips of the darts can be protruded beyond the end of the guide. Enclosing the three dark-coloured piercing structures there are two fleshy "sting palps," shown in lighter colour in the figure, which includes only the *terminal* part of the sting. When the bee strikes, the secretion of the poison-gland is forced down between the darts and the guide.

begins to make one's head reel—cell, nucleus, chromosomes, microsomes! But it is all fact.

Inside the nucleus there may be a nucleolus or more than one, and outside the nucleus there is a minute body called the centrosome, which plays an important part in the division of the cell. This is not nearly all, but it is enough to suggest *how complex is the microcosm of the cell.* Inside each of man's cells there are about two dozen chromosomes, and one of the authorities on cell-lore speaks of each chromosome having the corporate individuality of a regiment, the really indivisible living units being the beads or microsomes—which correspond to the men! And to this must of course be added the fact that we have many millions of these cells in our body. Indeed, we are fearfully and wonderfully made!

Every many-celled creature, which reproduces in the ordinary way, starts on the journey of life as a single cell—the fertilised ovum. As we have made clear in a previous article, the usually microscopic fertilised egg-cell contains, in some way that we cannot picture, the initia-



SURFACE VIEW OF THE COMPOUND EYE OF A FLY, SHOWING SOME OF THE THOUSANDS OF CORNEAL FACETS.
Corresponding to each facet is a complete " eye-element," including a double lens and a percipient retina or retinule.

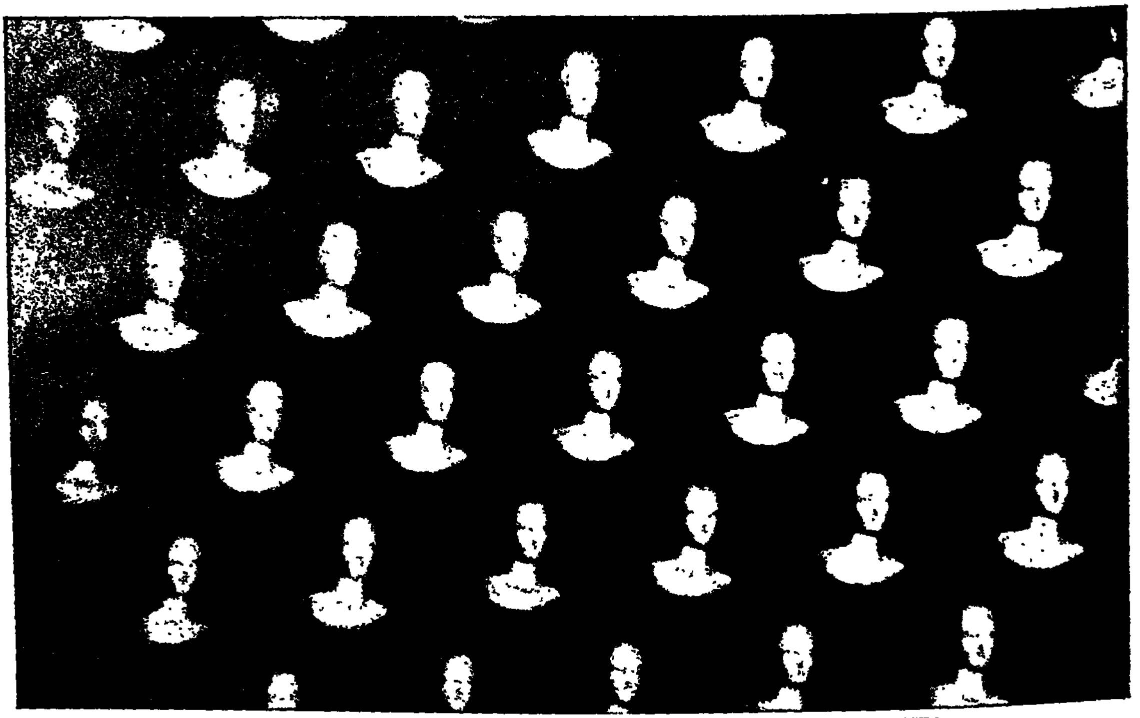


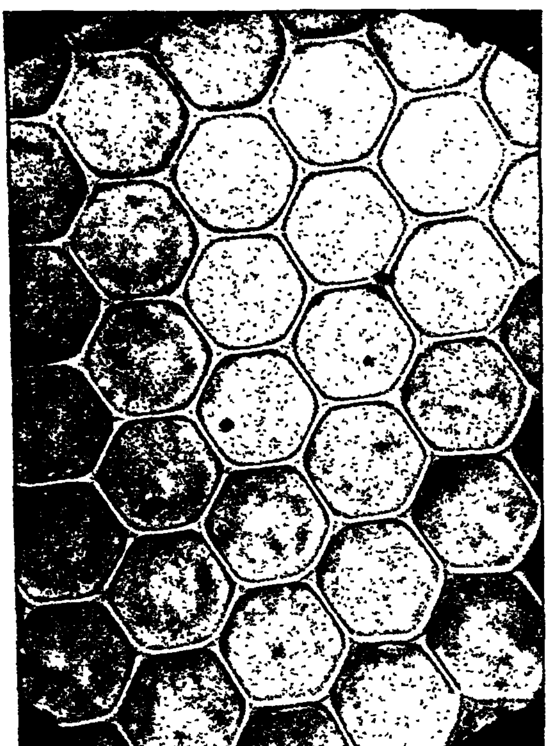
PHOTO OF STATUE TAKEN THROUGH THE LENSES OF THE FLY'S CORNEA.

A multitude of images has been formed, one image through each of the thousands of lenses. The photo-micrographs of the fly's eye were taken by means of Davidson's " Davon " Patent Super-Microscope, in which an achromatic combination called a " collector " is placed behind the objective in the microscope. This projects an " air " image of the object under examination beyond it, and this " air " image is magnified by another objective and eyepiece acting as a compound eyepiece. The result is that higher magnification can be employed on any given objective than is usually employed and without loss of resolution.

tives or "factors" for the hereditary characters of the living creature in question. But the microscope has begun to reveal the little world within the egg-cell, and it has been found possible to map out the way in which the factors for certain characters are disposed in the chromosomes. Thus in the case of the egg of the fruit-fly called Drosophila, it is possible to say that the hereditary or germinal factor for, say, red eye or grey wing, lies at such and such a level in one of the four chromosomes. *It would be difficult to find a wonder of microscopy greater than this.*

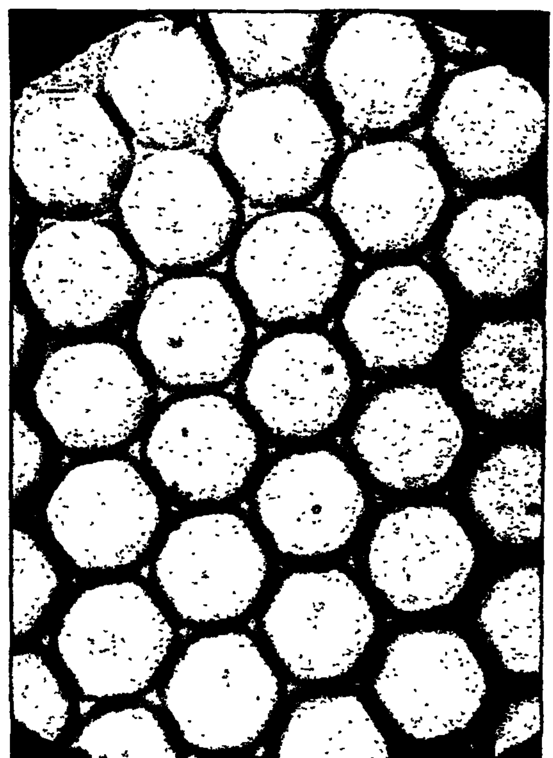
The Beginning of the Individual.

Yet this is but an instance of what goes on at a level of visibility which only the microscope can reach. We know much in regard to the permutations and combinations which take place when the germ-cell is ripening—shufflings of the hereditary cards which throw some light on the origin of new departures. We know something of the manner in which the paternal and maternal hereditary contributions behave in relation to one another when and after fertilisation takes place. We know much in regard to the sequence of events in individual development, wherein the obviously complex emerges from the apparently simple, and the implicit inheritance becomes an explicit individual. In the seventeenth century, William Harvey, the discoverer of the circulation of the blood, wrote in regard to development: "Although it be a known thing subscribed by all, that the fœtus assumes its original and birth from the male and female, and consequently that the egge is produced by the cock and henne, and the chicken out of the egge, yet neither the schools of physicians nor Aristotle's discerning brain have disclosed the manner how the cock and its seed doth mint and coine the chicken out of the egge." But although we do not understand to-day how the factors of an inheritance are condensed into the dimensions of a pin-prick; or how the fertilised egg-cell segments into two, and cleavage after cleavage continues, with associated division of



SURFACE VIEW OF THE COMPOUND EYE OF A FLY, SHOWING THE NUMEROUS HEXAGONAL FACETS ON THE TRANSPARENT CORNEA.

To the inside of the facet there is an outer or corneal lens, inside that a crystalline cone or inner lens, and inside that again a percipient rod.



SURFACE VIEW OF THE SAME EYE, SHOWING THE CORNEAL OR OUTER LENSES FITTING AGAINST THE HEXAGONAL FACETS OR FRAMES.

In the house-fly there are about 4,000 facets, corneal lenses, crystalline cones, and sensitive rods.

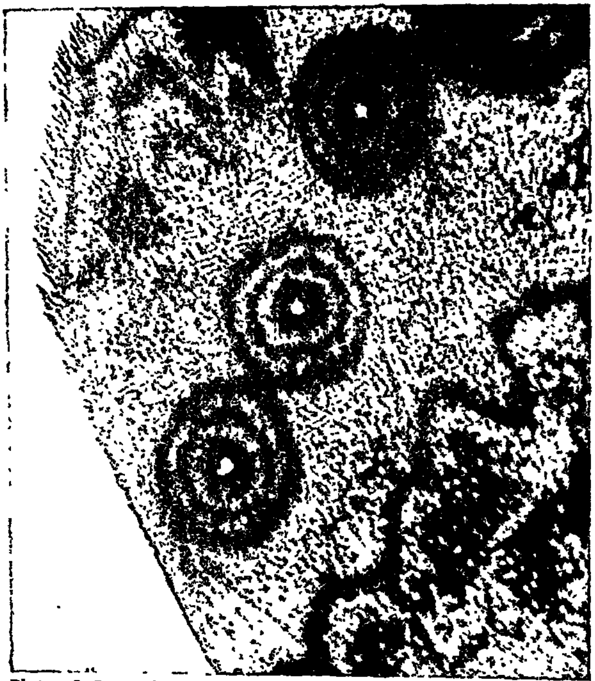


Photo: J. J. Ward.

PART OF THE WING OF A WALL-BUTTERFLY.

Showing how the numerous scales build up its design, not only covering the general surface like the slates on a roof, but arranged in wavy bands and concentric zones. Each microscopic scale is finely striated longitudinally, and the light falling on these undergoes "interference." This gives the metallic iridescence to the wings of many butterflies, greatly enhancing the coloration due to pigment.

labour, until an embryo is built up; we *do* know why it is that like tends to beget like, why certain hereditary characters are distributed in a particular way among the offspring. And we also know the successive steps by which the process of development is accomplished. It is this kind of knowledge, we think, which must be regarded as *the crowning wonder of microscopy*. These fundamental questions of heredity and development will be discussed in a separate article, but the point here is that the scientific study of inheritance can as little dispense with microscopy as with breeding experiments and statistics. All three are *essential*.

Manifold Uses of the Microscope.

Everyone knows that finger-prints are sometimes of critical importance in the identification of a criminal. The details of the pattern of the ridges on the fingers vary from man to man; they are *individual*. Therefore, if a good impression is available on some surface which has been handled in the course of a burglary, let us say, it can be compared with the collection in the album of criminals' finger-prints, and identification may follow. The microscope has even subtler use in *the detection of crime*. If splashes of blood on the clothes of a suspected murderer are declared by him to be due to the blood of a rabbit which he killed, it is usually possible to test the truth of his statement *microscopically*. For the dimensions of the very minute red blood corpuscles differ in different mammals, and the *circular* shape in all mammals (except camels) can be distinguished at a glance from the *elliptical* shape in all the other backboned animals. Moreover, the red blood pigment of hæmoglobin can be easily made to assume a crystalline form, and it is a very remarkable fact that the blood-crystals of the horse can be distinguished microscopically from those of the ass, and even those of the domestic dog from those of the wild Australian dingo. Poisons that crystallise may also be detected by means of the microscope.

The use of the microscope in *medicine* may be illustrated in reference to the blood. For it is often possible by microscopically

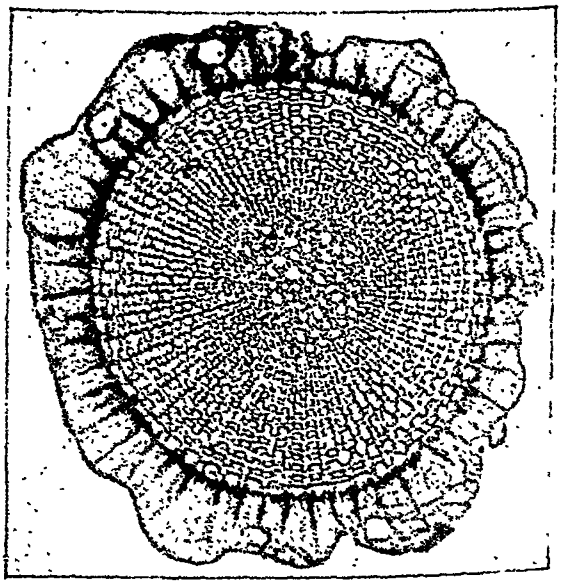


Photo: J. J. Ward.

CROSS-SECTION OF THE SPINE OF A SEA-URCHIN (*CIDARIS METULARIA*), MAGNIFIED SEVERAL DIAMETERS.

The remarkable feature is the beautiful zoned structure. The spine is a delicate needle to start with, but around this there is a periodic deposition of lime from the skin, one concentric zone after another. It is probable that this kind of architecture gives the spine great stability, but it is primarily an expression of rhythmic orderly growth. It shows that the quality of beauty is not confined to the outsides of animals.

Reproduced by courtesy of Messrs. F. Davidson & Co.

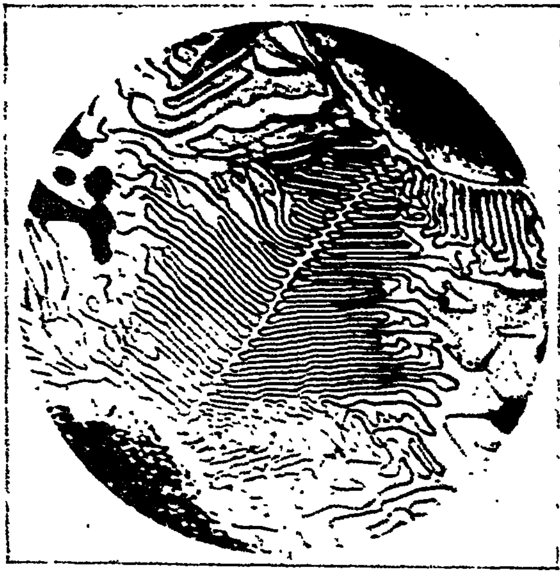
THUMB-PRINT IN WAX.

The skin is marked by numerous ridges and intervening valleys, which have individual peculiarities of pattern, even in the same family. This illustrates inborn variability. The individuality of the pattern is so marked that the prints are used as sure means of identification.

examining a film of blood, spread on a slide, to tell what is wrong with the patient. Microscopic parasites may be detected, like those of malaria; methods of counting the red blood corpuscles (man has trillions!) may show that they are far below the proper number; and a change in the normal shape of the hæmoglobin crystals may show that something is amiss. It is unnecessary to dwell on the medical importance of the microscope in determining the presence or absence of certain kinds of microbes and higher parasites in the blood or food-canal of the patient. Along with this physiological utilisation of the microscope we may take its use in testing drinking water, which is liable to be fouled by the presence of bacteria and various minute animals. Also of great importance is the microscopic study of milk, for this fluid is peculiarly liable to contamination, and is very suitable for the growth of various kinds of disease germs.

For *the detection of adulteration* the microscope is also invaluable. The starch grains of different plants, such as potato, wheat, rice, maize, are readily distinguished from one another, and a microscopic examination may immediately prove that a commodity sold under a particular name, e.g. as arrowroot, is not what it professes

to be. If a sample of so-called "honey" contains no pollen-grains, but a great many starch-grains, we may be sure that the busy bee was not the chief agent in its production. In short, the microscope is a valuable detective of dishonesty. But a use of the microscope more important and more pleasant to think of is in metallurgy, where its utilisation to detect the structural features of the stable and the transient in various metallurgical combinations, such as different kinds of steel, has been of inestimable importance.



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A PIECE OF HIGH-SPEED STEEL SEEN UNDER THE HIGH MAGNIFICATION OF 1,500 DIAMETERS.

Note the marked lines of flow.

A farmer can always make good use of a lens in examining samples of seeds, or in identifying particular kinds of injurious insects, or in detecting the beginnings of "rusts" and "mildews" on his crops. But the expert agriculturist must of course go much further, especially in warm countries, where the microscope is necessary for the study of the insidious Fungi which are always ready to find a weak spot in the plants' defences—in all sorts of plantations from coffee to rubber.

Photo: J. J. Ward.

SCALE FROM A GOLD-FISH.

Showing the rings of growth by which the age of the fish can be reckoned. Starting from a little speck, the scale has line upon line added to it. Periods of rapid growth alternate with periods of slow growth; or the growth in summer may be different in character from the growth in winter; and thus alternate zones are established. Just as we can tell the age of a tree by counting the summer and autumn rings on the cut stem, so, after getting some secure data, we can tell the age of the fish. It keeps its diary on its scales.

Early in the twentieth century an ingenious method was described by Siedentopf and Zsigmondy, which is often briefly referred to as the *ultra-microscope*.

The Ultra-Microscope.

Everyone knows from personal observation that a strong beam of sunlight entering a darkened room reveals a multitude of dust particles, which are not seen at all in ordinary light. The same multitude of particles is often seen in the track of a strong beam from a "magic lantern" in a darkened room. These dancing particles, whose abundance we scarcely suspected, become visible because they are so strongly illumined; there is a diffraction of rays from their surface, and they look much bigger than they really are.

In 1899 Lord Rayleigh pointed out that a particle too small to be seen by the highest power of the microscope under ordinary conditions might be made visible if it received sufficiently intense illumination; and the ultra-microscope took advantage of this idea. It occurred to Siedentopf and Zsigmondy that if the particles in a solution could be strongly illumined by a beam coming in, so to speak, sideways, then

particles ordinarily invisible might stand out. Their diffraction-images, at any rate, would be seen. In ordinary microscopic conditions the beam of light is thrown by the mirror, usually through a sub-stage condenser, directly through the solution or thin transparent section, up into the tube of the microscope, where an image is formed, to be re-formed by the eyepiece. In the ultra-microscope for examining solutions the beam of light is projected *horizontally* into the solution and examined from above. The result is that particles ordinarily invisible are seen in a vigorous dance, the so-called Brownian movement. This dance is due to the particles being bombarded by the moving molecules of the fluid in which they are suspended. By accessory devices it becomes possible, in the use of the ultra-microscope, to count the number of particles in a solution and to measure the mass of each. This has formed the basis of exceedingly interesting conclusions which are unfortunately beyond our scope in this article.

A reference should be added, however, to another method called "dark-ground illumination" which makes structures visible which are

Photo: J. J. Ward.

FEET OF THE JUMPING-LEGS OF THE COMMON FLEA.

The powerful muscles which give the flea its familiar power of leaping are mainly in the uppermost part of the leg, which is not shown here; but there are minor muscles continued to the very tip of the legs, to the base of the terminal claws. Note the numerous bristles or setæ on the leg.

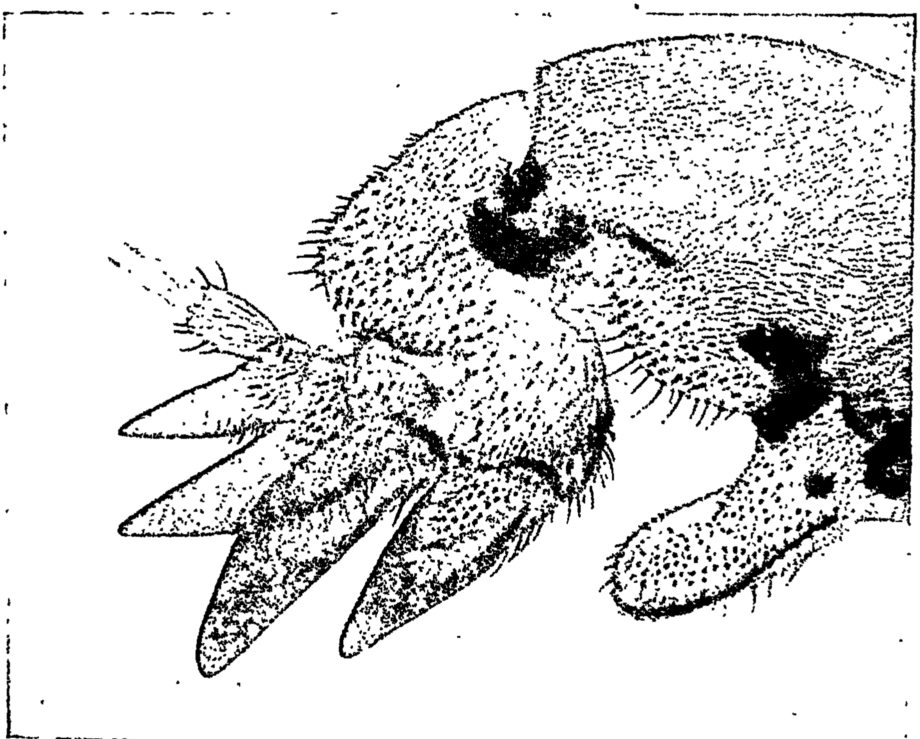

Photo: J. J. Ward.

ONE OF THE FORE-LEGS OF THE MOLE CRICKET (GRYLLOTALPA).

Showing very strong digging blades, reminding one of the mole's claws. Small forceps are also seen, and an oval mark on the "knee" is a sense-organ sometimes regarded as an "ear." The Mole Cricket is nearly related to crickets and grasshoppers and is a very powerful burrower.

invisible in ordinary conditions of microscopic work. Professor Bayliss writes: "The central rays of the illuminating beam are cut out by means of a stop, and the peripheral rays are reflected by a parabolic surface so as to meet in a point in the object under examination; they cross at such an angle as to pass outside the field of the objective in use, which only picks up the light refracted, or diffracted, from structures in the preparation." The dark-ground illumination brings out features which are invisible in the ordinary direct illumination.

The essential parts of a microscope are, as we have seen, (1) the objective for obtaining the first magnified image of the object; (2) the ocular for further enlarging that image and transmitting it to the observer's eye; and (3) the sub-stage condenser for illuminating the object with a cone of light. Now, in modern times, there have been numerous detailed improvements in these parts, e.g. in the quality of the glass used in making the lenses; and a present-day microscope is certainly a very perfect instrument. Indeed, unless some new idea is discovered, such as those behind the ultra-microscope and dark-ground illumination, it does not seem likely that great advances in technical microscopy can be made. The reason for this statement is to be found in the optical limitations of the instrument. The use of the microscope is not mainly magnification but *resolution*. "By resolution," says Mr. J. E. Barnard, "is meant the power the objective has of separating and forming correct images of fine detail." Unless we see more of the intimate structure, the magnification in itself does not greatly avail. It does not help us to understand the thing better. Now there are two factors that determine this "resolving" power of the microscope. The first is what is called the "numerical aperture" of the lens, which means, in a general way, the number of divergent rays of light that the curvature of the lens will allow to impinge upon it. Lenses of high magnifying power are so small that they admit only a very small beam of light. Thus what is gained

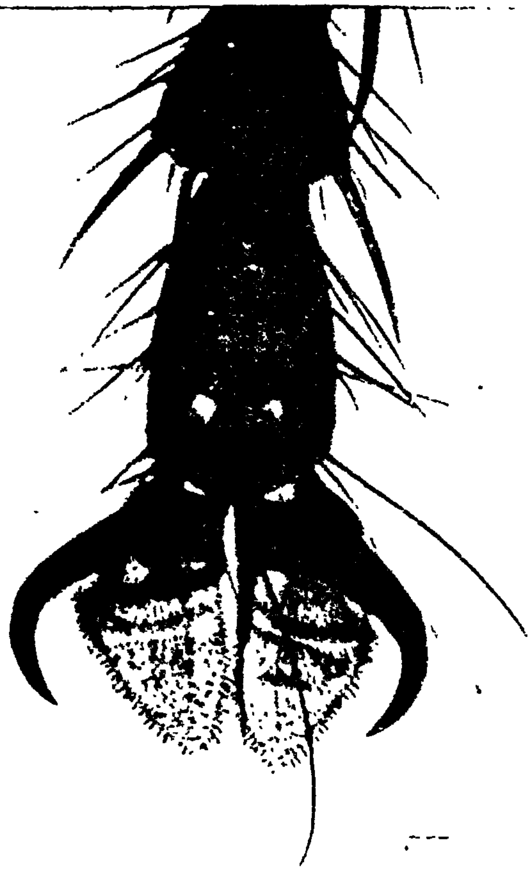

Photo: J. J. Ward.

FOOT OF A HOUSE-FLY.

Showing two claws for gripping minute roughnesses and, between the claws, a double pad or cushion which is used in climbing up a smooth surface like a window-pane. The probability is that a moist secretion from the pad helps the adhesion. There is also very close apposition of the cushion to the smooth surface, and some say a partial vacuum is formed. But we are not quite sure how a fly runs up a window-pane—one of the most familiar sights in the world.

in magnifying power may be lost because of deficient illumination. A pretty device to increase the income of light in these high-power lenses was the "immersion lens," made of such a curvature that when the lens was focussed down into a drop of oil, or some other liquid, placed over the object on the slide, it received light from all sides. The drop into which the lens is focussed down or "immersed" greatly increases the illumination of a lens with high magnifying power. This method has enhanced the value of the microscope as an instrument that analyses structure, or, in other words, that discloses the intimate architecture of things. But the main point is that the "numerical aperture" of even the oil-immersion objective has at the present time reached its practical limit.

Yet there is a second factor, and that is the wave-length of the light-rays that impinge from the mirror and condenser on the object on the slide. But here again there is a limit, for, as Professor Bayliss tersely puts it: "Any object smaller than half the wave length of the light by which it is illuminated cannot be seen in its true form and size owing to diffraction. Hereby is set a limit to microscopic observation." These are difficult matters, but the important point is that there are practical limits to what the microscope can do in the way of magnification and "resolution."

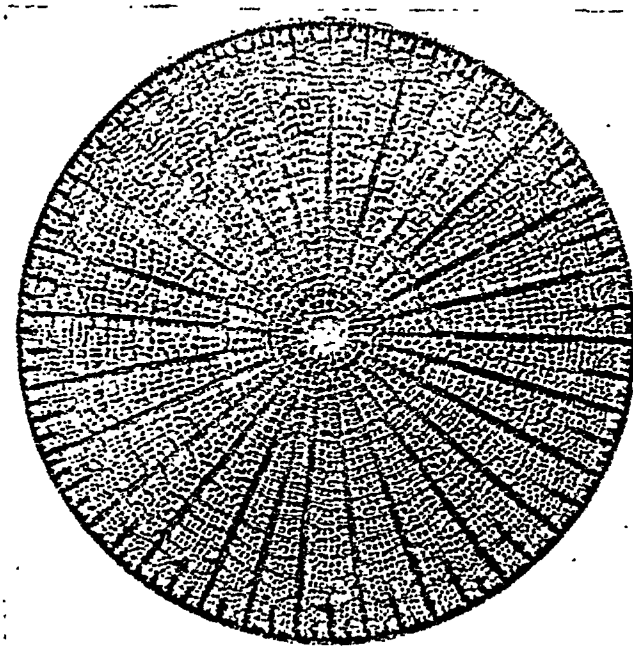

Photo: J. J. Ward.

THE BEAUTIFUL PATTERN ON THE MICROSCOPIC FLINTY SHELL OF A DIATOM (*ARACHNOIDISCUS EHRENBERGI*), A KIND OF UNICELLULAR PLANT.

Two hundred of these cells placed side by side would scarcely extend one inch. It is not known that there is any utility in these beautiful markings. They are expressions of rhythmic orderly growth.

But Mr. J. E. Barnard has recently made an interesting step forward by using an illuminant such as a mercury vapour lamp, which is rich in blue and violet radiations. It may also be practicable to utilise invisible radiations in the ultra-violet, which would further increase the microscope's resolving power. As things are at present, the limit of useful magnification is somewhere about 800 diameters.

We cannot close this article without referring to a very different subject—namely, the extraordinary beauty of many microscopic objects. There are endless "beauty feasts" to be found in the architecture of the shells of diatoms, Foraminifera, and Radiolarians; in the structure of the outside of pollen-grains and butterflies' eggs; in the zoned internal structure of the stems of plants and the spines of sea-urchins; in the sculpturing of the scales on butterflies' wings and the multitudinous hexagons of their eyes; in the strange hairs on many a leaf and the elegant branching of zoophytes; in the intricate section of a rock and the variety of snow crystals. Of microscopic beauty there is no end.

Beauty of Microscopic Structure.

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X

THE BODY-MACHINE AND ITS WORK

THE most perfect machine in the world is the body of man. The further we advance in our knowledge of it, the more we wonder at the ingenious mechanisms which are crowded into its structure. Almost every decade we discover new operations in it which have a profound influence over our life, yet are so subtle and unexpected that many generations of scientific men were entirely ignorant of them, and it may take still many generations to tell how they bring about their marvellous results. Here, as in other fields, the advance of science creates one mystery while it explains another. But that story of evolution which we studied in a preceding section sheds a clear light upon the body-machine both of animals and of man, and enables us to understand the high efficiency of most of its parts. The machine of the animal body is not only the most perfect in nature; it is immeasurably the oldest. For at least fifty million years—how much longer no man knows—the world-forces have been making the animal body, developing and improving the various organs and co-ordinating their functions. During all these tens of millions of years the machine has been subject to the fiercest stresses and trials, and the human body, as we know it, is the final and finished outcome. We wonder no longer. Time itself makes nothing; but if we grant a vast period of time to the real shaping forces of the universe, acting upon the most sensitive material in the universe, the perfection of the final stage becomes intelligible.

§ 1

Traces of the Past.

We speak of the body as a machine, but it is hardly necessary to say that none of the most ingenious machines set up by modern science can for a moment compare with it. The body is a self-building machine; a self-stoking, self-regulating, self-repairing machine—the most marvellous and unique automatic mechanism in the universe. It differs from our ordinary machines, moreover, in this: when a part becomes superfluous or out of date, it will linger for ages, even for millions of years, in the structure, slowly changing and shrinking on its way to disappearance. It will be useful to begin our examination of the human body from this point of view, especially as some of the first things we notice about it are precisely shrinking structures of this kind.

Why have we hair on our bodies? We need not notice here the specially luxuriant growth on the head, or on the man's lips and chin. This has been artificially fostered or cultivated during the course of man's history. Men, in mating, chose women with rounded forms and smooth chins. Women chose men with strong, muscular forms and, in our own branch of the race at least, hairy mouths and chins. We quite understand that in the course of tens of thousands of years this has evolved rich growths of hair in certain parts. But we have hair on our trunk and arms and legs; there are tiny pits in the skin, out of which hairs grow, all over the body except on the palms of our hands and the soles of our feet. Before birth the human body is, in fact, almost entirely covered with a fine coat of hair.

There is not a word to be said in favour of this part of our wonderful body-machine. It harbours dirt, microbes, and vermin, and sometimes favours skin-disease. As a coat it is ridiculously thin and ragged, and it has been superseded by clothing. Its plain meaning is in the story of life in the past which was told in an earlier part of this work. The hair is a dwindling vestige of the warm fur-coat which mammals developed to meet the conditions of an Ice Age. It is *vestigial*, not rudimentary, as is sometimes said.

The pieces of gristle or cartilage on the sides of the head which we call our "ears" are similar organs. They do not catch waves of sound, as

many suppose, and guide them into the real ear inside the skull. They are too flat to do so. But if we compare them with the useful, pointed, movable ear of a horse, we see what they mean. They were once similar organs, but they have fallen out of use and are dwindling away. Underneath the skin we still have seven muscles attached to the shell of cartilage, from which it is obvious that the ear could once be moved in every direction to catch the waves of sound. Now only an individual here and there can use one or two of these muscles. The pinna or "ear-trumpet" is a surviving structure that tells us a little about the body's remote past.

There are very many similar muscles in the body to-day which merely tell us about a strange past. Some men can twitch their nostrils. Some can move their scalps. They do so by means of muscles which in most of us have gone completely out of use. Underneath the skin in very many parts of the body there are dwindling muscles of this kind.

In the inner corner of each eye we have a little pulpy mass which recalls to us even remoter ages of the body's past. It is of no use whatever in the body to-day. To understand it, one has to watch a parrot or an eagle in a cage, and notice how the bird flashes a white film (the "third eyelid") occasionally over its eyeball. Our superfluous bit of tissue is the shrunken remainder of this. We have in our eyelids a better apparatus for sweeping the dust off the eyeball, and the old membrane is disappearing. Man is not, of course, descended from birds, but almost all mammals have a well-developed third eyelid.

We know from fossil remains and from examining the bodies of living reptiles that in remote ages—somewhere about the era of the Coal Forests—there were animals with a third eye, in the top of the head. We find this third or pineal eye in the heads of a few reptiles to-day, but the skin has grown over it, and it is degenerating. In the birds and mammals it has sunk still deeper into the head, and degenerated further. In man it has become a small body, about the size of a hazel-nut, rising from the middle of the brain. We call it the "pineal body." It is a mysterious little organ, and we will not say positively that it has no function. But, whether it has or no, we clearly trace it to the third eye of millions of years ago.

The "vermiform appendix" is a well-known vestigial organ. It is a little worm-like tube, about four inches long, arising as a blind alley at the junction of the small and the large intestine; and as a source of disease (appendicitis) and danger it is notorious. Some have tried to find that it has a use in the body, but the plain fact is that it has been removed from hundreds of thousands of men in modern times, and no harm has ensued in any single case. It is the vanishing remainder of a large, useful chamber in which early vegetarian mammals let myriads of bacteria break up their coarse food.

In short, expert investigators of the human body have found 107 organs, or parts of organs, that have to be understood as more or less vestigial. We have the vestige of a tail in the block of bone at the lower end of our backbone; and sometimes children are born with distinct and movable—though very short—tails. We have bones, muscles, and glands in many parts that are now the almost or quite useless relics of a remote past. Evolution beautifully explains them. The body remains a wonderful mechanism because these were once useful and most cunningly contrived structures.

§ 2

The Ivory Gates of the Body.

Turning now to the body-machine in its active life, we shall find it most interesting to follow the progress of food until it is built into the frame. We can, if we like, do this literally to-day. We can mix an opaque powder, e.g. of bismuth, with a mouthful of easily digested food (such as meal), and then by means of X-rays we can photograph its progress along the alimentary canal until what remains of it is dumped in the waste-chamber. This is useful for some purposes, but in the main we rely on the minute studies of the anatomist and the experiments of the physiologist for our knowledge of that part of man's body that is concerned with the utilisation of the food.

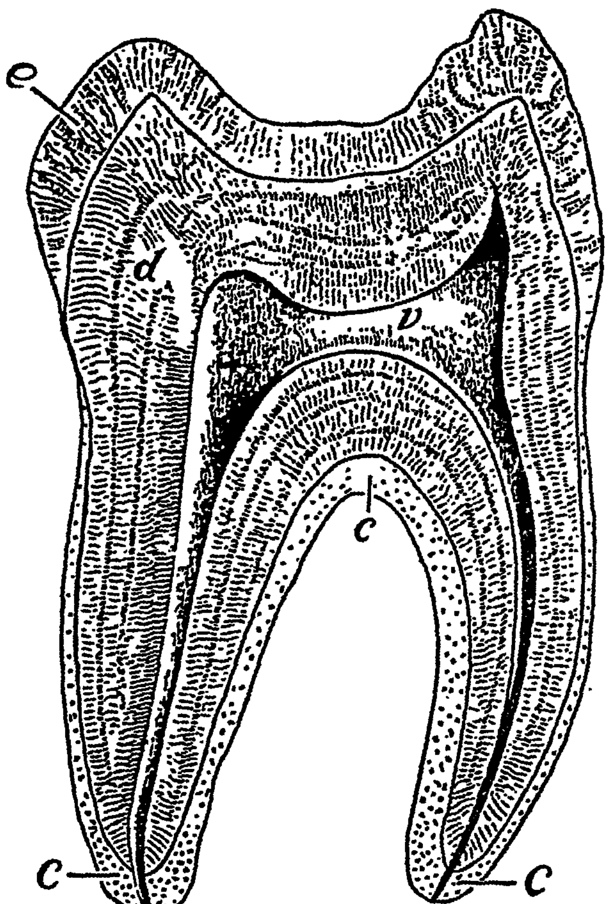
The receiving office, so to say, or the mouth, is itself so deeply interesting and full of ingenious contrivances that a whole section of this work

Photo: Alinari.

DR. JENNER (1749–1823) INNOCULATING HIS OWN SON: THE STATUE BY J. MONTEVERDE AT GENOA

He proved about 1796 by a long series of observations and experiments that vaccination with cowpox protects the body from smallpox, either completely or to the extent of diminishing the severity of an attack.

might be devoted to it. Above the mouth are the sentinels, the eyes and nose, which we shall consider later. Then, on the upper surface of the tongue, there are myriads of sensitive little organs, taste-buds, ready to apply a final test to the food. The juices of the food penetrate the thin skin which covers and protects them, and probably have a chemical action on the little nerve-endings in them. If the message which they automatically dispatch to the brain is "O.K." other nerves set in motion the muscles of the lower jaw, and the grinding of the food begins.



VERTICAL LONGITUDINAL SECTION (AFTER OWEN) OF A HUMAN MOLAR TOOTH.

The lower part is embedded in a socket in the jaw and surrounded by the gum—the derma of the dense mucous membrane of the mouth. Two roots or "fangs" are shown, surrounded by a thin layer of bone called "cement" (*c*). Through the basal openings shown there enter blood-vessels and nerves. In the centre of the tooth is the vascular pulp-cavity (*v*), from which fine processes extend into the ivory or dentine (*d*). Over the crown there is the enamel (*e*), the hardest tissue in the body.

In modern times a volume could be written on the teeth alone, and it would be a remarkable story. Teeth began ages ago in fishes of the shark and dog-fish type. Their rough scale-covered skin was drawn in to form a lining of the mouth, and long practice in crunching shell-fish, and so on, led to the evolution of the hard scales on the skin into teeth. In the course of time the teeth on the ridges of the jaw were particularly developed, and the others disappeared. But we must not suppose from this brief hint of their origin that teeth are simple things. Each tooth is a remarkable structure. Coats of dentine and enamel are built round a pulpy cavity into which nerves and blood-vessels run, and roots. coated with cement, fix the tooth in its socket. It is strange how few people wonder why our jaws do not ache and jar from the crunching of a hard crust. In mammals there is a provision which obviates this: the teeth do not fit tightly in the sockets. They are "packed" in with a material that lessens the shock of the daily grind.

A special regiment of the cells which make up the body is told off to see to this business of the teeth, and our wonder increases when we see these strange microscopic, unconscious "bone-builders." They have, in the baby, to select, atom by atom, the cement and dentine and enamel which (in other forms, of course) somehow exist in the food of the blood-stream. They have to build the stuff into structures of which our artificial teeth are very clumsy imitations. They have to do this at the right time—to wait until suckling is over and eating begins. Then they have an even more difficult problem to face. The jaws of the adult will be much larger than the jaws of the young, and, naturally, it is not possible to alter these solid structures of enamel and dentine. So the bone-builders absorb the greater part of the first set of teeth, the "milk-teeth," and meantime prepare a new set underneath them. The cast tooth which your child shows you is, as a rule, a mere shell. The microscopic bone-builders have re-absorbed the material.

Yet the teeth, with all their wonders, may be among the doomed structures of the body. Some authorities believe that they will gradually drop into the class of vestigial organs, like the hair,

though they will give a vast amount of trouble as they grow weaker. Their purpose is to break up the food into smaller particles, and in modern civilisation this is done in the preparation and cooking of the food. So the teeth are already going. In ancient skulls and among savage peoples the teeth are often much worn away by sheer hard work; in conditions of civilisation much-worn teeth are rare. The jaws have not the hard work they once had; they therefore get a smaller supply of blood, and the teeth grow weak and less numerous. Normally we have thirty-two teeth, but in many people the so-called "wisdom teeth" (which might very well be called unwisdom teeth, as they are superfluous) do not develop. On the other hand, a few people have thirty-six teeth, and when we turn to the monkeys we find that some of them have this number. We are, in fact, slowly shedding our teeth, in fours, along the corridors of time, and it may be that in the distant future man will be toothless. Perhaps, however, a fresh enthusiasm for physical vigour will save the race from any such degeneracy.

Photo: Elliott & Fry, Ltd.

PROFESSOR E. H. STARLING.

One of the leaders of modern physiology. He has made contributions of the highest importance towards an understanding of the chemical correlation or harmonious working of the body, notably by his study of internal secretions. Professors Bayliss and Starling have done much together.

But our "grinding-stones" are only part of the mechanism of the mouth. As soon as the grinding begins three pairs of glands pour saliva into the food. Here again we have an automatic nervous machinery of a remarkable kind, for, as everybody knows, the mere sight of food may set the glands at work, or "make your mouth water." In the glands themselves the microscopic cells which make the saliva are such remarkable chemical machines that we cannot yet understand them. They not only help to make a soft pulp of the food—the saliva is 99 per cent water—but they pour into it certain chemicals which begin the digestion of starchy food, converting it into a kind of sugar. That is one of the reasons for thorough "mastication." One must not suppose that it does not matter, since the food is so short a time in the mouth that there cannot be much chemical action on it. The chemical action of the saliva *goes on*, for half an hour or more, while the food is in the stomach. A great deal of illness is due to neglecting to mix plenty of saliva with our bread, etc., before it leaves the mouth.

§ 3

The Process of Digestion.

When teeth and salivary glands have done their work, and the taste-buds on the tongue have had their moment of satisfaction, the mouthful of pulp is swallowed. "Swallowing seems such an easy and automatic act that we are quite unaware of the elaborate system of signals, side-shunts, and level-crossings which have to be manipulated to permit the busy traffic of the pharynx to pass unchecked." Food does not "go down," as children think. The whole mouth changes. Certain sensitive spots at the back of the mouth—electrical press-buttons, we may call them—give the signal that the food is ready. The powerful muscles which closed the back of the mouth while we were masticating, relax. The lower jaw is pressed against the upper. The soft palate forms an inclined plane.

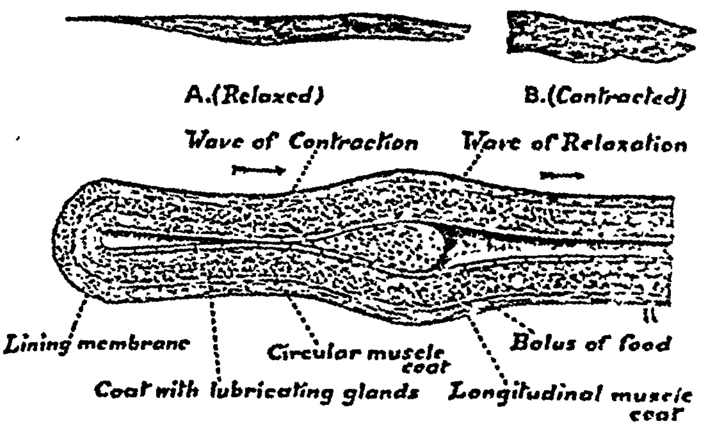
Other muscles close the airways to the nose and the great airways to the lungs. The whole complex machine acts together and pumps the food into the first part of the alimentary tube, the pharynx. Only very rarely does a little food "go the wrong way"—into the air-passage—and then another set of muscles automatically blow (or cough) it out. The mouth is a rather complicated cavity. How many communications it has—with the nasal passage by the posterior nostrils, with the ear-passages by the Eustachian tubes, with the pharynx, and with the windpipe through the guarded glottis. It is obviously very important that the mouth be kept in good order.

The food now enters upon a very long journey. Most people are surprised to hear that the alimentary tube is yards long in a man or woman of medium height, about twenty-eight feet long from the mouth to the vent. But few people reflect—there would be far less misery and discomfort in the world if they did—what digestion really means. Our food has to be broken up, physically and chemically, and even then it cannot pass into the blood. From the pulpy mass myriads of tiny organs have to select the matter which the body needs, and let the remainder pass away. So the food has to pass slowly through twenty feet of a long tube, the small bowel or small intestine, to give these "selectors" the chance of taking the nourishment from it.

However, let us begin at the beginning. The food passes to the stomach down a one-foot tube (in a man of medium height), the upper part of which is known as the pharynx, and the lower part as the gullet or œsophagus. As we said, it does not slide down.

Sir Arthur Keith describes very graphically the transport of a bolus of food towards the stomach. "The instant that a bolus has been pushed through the doorway leading from the pharynx, and that doorway has closed, we see a ring of contraction form behind the bolus and commence to creep slowly downwards, forcing the bolus in front of it. The bolus, on entering the œsophagus, has touched a 'button,' and the ring of contraction is the result. As the bolus is driven forwards it comes in contact with a succession of such buttons, with the result that it is kept moving onwards. Not only so; a ring of relaxation precedes the bolus and eases the passages." [1]

The earliest stomach in the animal world was merely a straight tube through which the food passed, but in the course of evolution it has grown larger and larger at this spot until (in man) we have a large storage chamber in which the food



Reproduced by permission from Keith's "The Engines of the Human Body" (Williams & Norgate).

A PORTION OF THE ŒSOPHAGUS OR GULLET LAID OPEN TO SHOW A BOLUS OF FOOD PASSING DOWN.

It will be seen that the muscular wall of the gullet relaxes in front of the bolus of food and contracts behind it

A, a small fragment of the outer muscular coat magnified to show the relaxed and spindle-shaped muscle fibres of which it is composed in a relaxed state. B, the same muscle fibres or spindles, greatly enlarged, showing the contracted state

in its muscles, and this is telegraphed to the brain by the nerves. You feel "hungry."

The inner wall of the stomach is richly supplied with blood, and is lined by the myriads of minute glands which produce the "gastric juice." As soon as you sit to table, the sight and smell of the roast mutton send their messages to a certain nerve-centre, and from this a silent message or stimulation goes to the glands. When the food touches the taste-buds on the tongue, the messages multiply. The blood gathers in the wall of the stomach, and the little tubes use its nourishing solution in order to make the digestive juice which they pour out upon the food. With a large part of our food the stomach does not deal. Digestion only begins in it. Sugars, starches, and fats are passed on to the next department. It is chiefly the nitrogenous or protein food—flesh, fish, eggs, etc.—that is here broken up still further and prepared for absorption. The stomach itself absorbs only a little of the food. A glass of wine—as the head of an inexperienced maiden may tell her—is absorbed into the blood very quickly, and part of the digested meat is passed into the blood-system through the stomach; but the main part of the food passes into the twenty-foot laboratory of the narrow "small intestine," to be further digested and absorbed.

It is amazing how few people have even a rudimentary knowledge of this fundamental part of their being. Stomach and bowels are hopelessly confused, and our poor organs, magnificent as they are, are treated with inconceivable crudeness even by educated people. It is easy for everybody now to obtain a list giving the exact digestibility and nutritive value of different kinds of foods. It should be known to everybody that the work of these myriads of minute chemical laboratories in the stomach has drawn the blood from the brain for a time, and it is unnatural and unhealthy to attempt brain-work during or after a meal. Half the physical misery of life could be cured by a little knowledge and restraint.

§ 4

A Remarkable Mechanism.

A brilliant physiologist, Professor Metchnikoff, startled us some years ago by stating—almost snorting—that the human alimentary system is a miserable out-of-date machinery that ought to be scrapped. Even the stomach, he said, was superfluous. Very few men of science agree with him, but when we understand what he was driving at, we see that he had hold of a very important idea. Professor Metchnikoff meant that we can "digest" our food in advance by means of chemicals, and get rid of all the great length of intestine which is so liable to disease. At present we take in great masses of superfluous stuff, but there will some day be extraordinary changes in man's diet. In the meantime the organs are there and we have to feed accordingly; but it does not follow that this will continue.

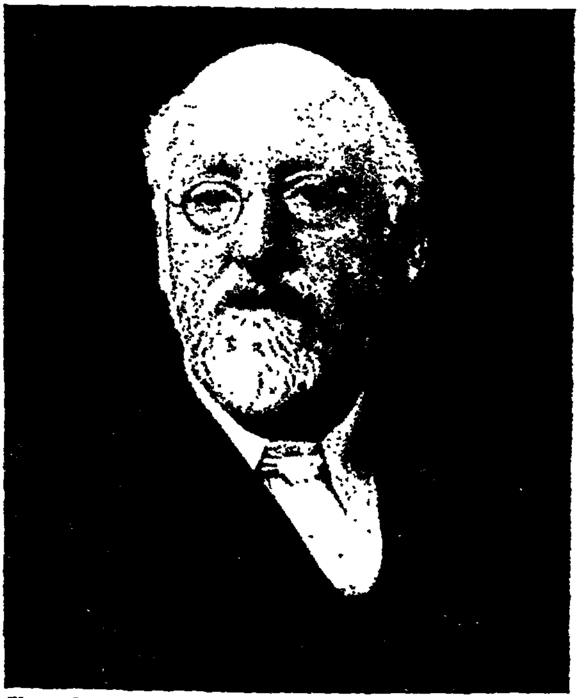


Photo: Russell, London.

PROFESSOR W. M. BAYLISS.

One of the leaders of modern physiology. He has made contributions of the highest importance to the study of internal secretions, digestion and the action of ferments, electric phenomena associated with vital processes, the production of heat in the body, and the regulative functions in general. His *Principles of General Physiology* is one of the great books of the science. Professors Bayliss and Starling have conducted many investigations together.

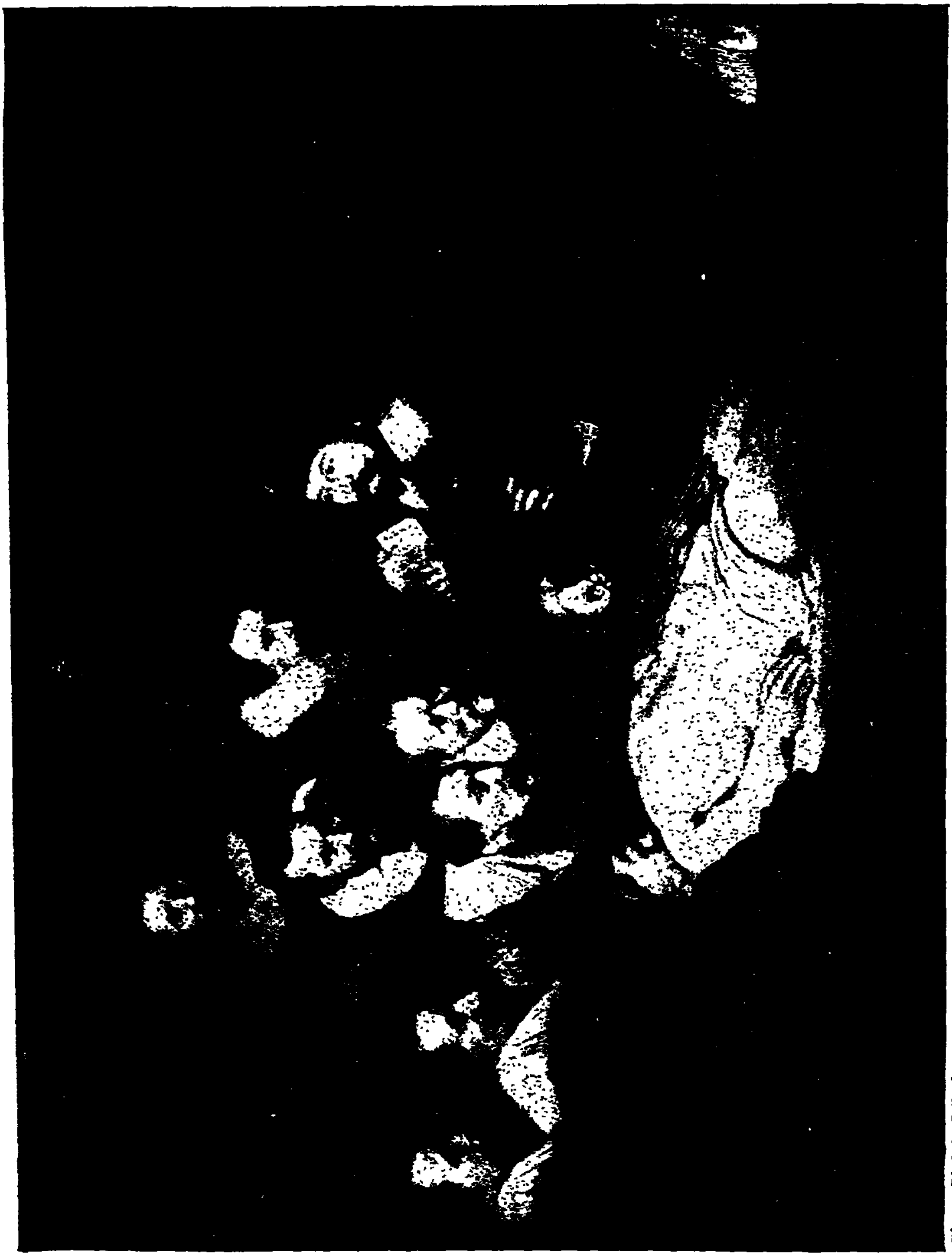


Photo: Rischgitz Collection.

THE SCHOOL OF ANATOMY, BY REMBRANDT.

At the base of the stomach, where the alimentary canal again becomes a tube—the beginning of the small (or narrow) intestine—there is a very powerful ring-muscle, which guards the exit. Nature has provided for healthy living. The unprepared food, if we live well, cannot run into the bowel. Mere contact of food against this muscle only draws it tighter. There has to be, apparently, some sort of chemical action by food which is quite ready, then the muscle relaxes, and a spray of the pulp shoots into the bowel. We can see the occasional gush when we are following the digestion by means of X-rays.

Photo: Kischgitz Collection.

SIR JAMES YOUNG SIMPSON (1811–1870),

who introduced in 1847 the use of chloroform as an anæsthetic. He was Professor of Midwifery in the University of Edinburgh and was indefatigable both in research and in practice.

In the first section of the narrow intestine, the duodenum, very important work goes on. Here we find a remarkable sort of mechanism which has only been discovered by recent science. The automatic machines of the body generally work by nervous action. The sight of roast beef is "wired" to the brain by the eyes, and a reflex (or reflected) nervous action sets the salivary glands and the stomach glands at work. This is a sort of automatic telegraphic system. But there is also in the body something like a postal service; it is one of the most wonderful discoveries of modern physiology. When, for instance, the acid food (or chyme) from the stomach touches the walls of the lower bowel, the glands in this wall form a certain chemical (called *secretin*) and pour it into the blood. The blood takes it rapidly all over the body, *but there is only one organ (or perhaps two) waiting for it.* In this case the pancreas (or sweetbread) receives the chemical message, and sets more vigorously to work pouring an increased supply of digestive juice into the intestine. These marvellous messages which are, as it were, posted in the blood are called "hormones," and, as we shall see later on, we find them again and again accounting for very remarkable results in the body.

The liver and the pancreas are really outgrowths from the alimentary tube; sections which have become detached, special departments, with ducts leading to the bowel. Each pours about a pint of fluid daily into the bowel, to assist the work of digestion. The liver has very special work to do, and we shall notice it presently. Here we need only say that the bile which it pours into the bowel—sometimes so abundantly that some forces its way into the stomach, and you get "bilious"—is not a digestive juice, but it helps to prepare the fats in the food. The pancreatic juice, on the other hand, is a real digestive juice, and the starches and sugars and fats, as well as the nitrogenous foods, are now dissolved and made into emulsion, and prepared, in short, for absorption. The juices of the pancreas and of the intestine include powerful ferments, or *enzymes*. These are substances which cause chemical changes by their mere presence, *without being used up in bringing about these changes.* One of them deals with the starches and sugars in the food, another with the fats, another with the proteins, like white of egg.

The chyme—the pulped and semi-digested

food—moves slowly along the bowel. In the bowel wall are muscles which contract, and drive the contents slowly onward at about one inch a second. But the interior wall of the tube is now lined, not only with glands, but with little outstanding fingers, like (on a microscopic scale) the pile on fine velvet. The surface is, moreover, puckered into folds, to give a larger area, and myriads of the tiny fingers or *villi* dip into the chyme and absorb the nourishing matter. Altogether about sixteen square feet of absorbing surface are given in the small intestine, and it is there that most of our nourishment is taken into the blood or the lymph. The rest passes on into the "large intestine," a very much wider tube at its lower extremity.

It is just at this junction-point of small and large intestine that the vermiform appendix is given off from the tube. Its opening into the bowel is very narrow, and sometimes bits of hard food, such as fruit-seeds, get into it and set up inflammation. Now in certain vegetarian animals like the rabbit the appendix is at the end of a large and useful blind alley or cæcum. A good deal of vegetable matter is wrapped up in cell-walls of cellulose, and the digestive juices we have described have very little power to deal with cellulose. It has to be broken up by bacteria, in such a chamber as the rabbit's blind gut or cæcum. The human vermiform appendix is a remnant of the large magazine in which some coarse-feeding ancestor of man had the cellulose of his food dealt with by bacteria.

Most people are inclined to shudder when they hear of bacteria in their bodies, but it is only certain kinds of bacteria that pour poisons into the blood and cause disease. Each one of us houses billions of friendly bacteria in the large intestine. They do us no harm, however, but break up the cellulose (the husks of grain, etc.) and multiply prodigiously in the fetid, fermenting mass in the intestine. Some physiologists think that we should be better without the large intestine, but, while there is little food absorbed from it, much of the water we take up is absorbed there. In any case, there the structure is, and the wise man takes plenty of cereals, fruit, and green vegetables in his food, to keep it in a state of healthy activity.

§ 5

The Vital Fluid.

Let us return to the nutritive material which has been taken up into the system. The tiny organs on the bowel wall which absorb it pass most of it directly into the blood-vessels which they contain. It becomes part and parcel of the blood, and will now, after passing through the liver, be pumped round the body *for the various organs to select from it the nourishment they need.*

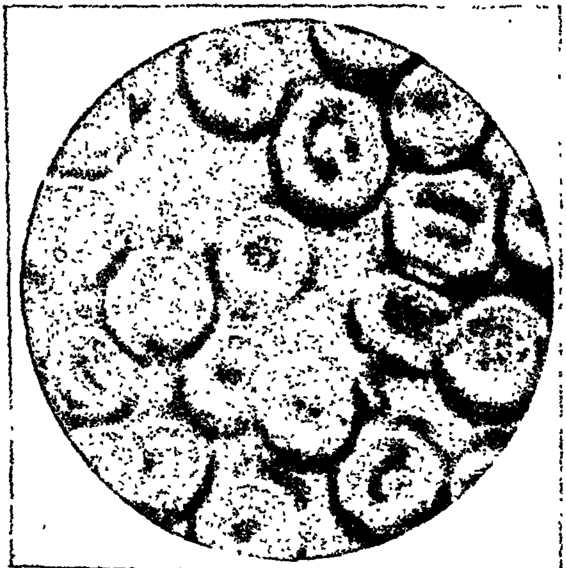
But blood is not the simple matter which it seemed to our ancestors; indeed, it has proved of late years to be full of subtle interest. If you prick your finger with a needle, and put a small drop of blood under the microscope, you see myriads of little disks, many of them in rows like columns of pennies, in a watery or yellowish fluid. The fluid—the serum or plasma—is the liquid food of the body and the medium for conveying away the soluble waste matter. The red disks or "corpuscles" are the bodies that convey oxygen from the lungs to the tissues. There are about five millions of them in every cubic millimetre of the blood of a healthy man —a woman's allowance is half a million less— and it is these which give the blood its red colour. We have about twenty-five trillions of them in all.

Thus the microscope discovered a new and unexpected complexity in the blood, and further research has shown that it is the iron-containing pigment in these red corpuscles which is chiefly concerned in the carriage of oxygen. There is very little iron in the blood, and it is absurd to think that we increase its quantity (once it is normal) by eating things "with iron in them," as people say. But what iron there is may be called a precious metal in the human body, and the red corpuscles have it in a form that still more or less baffles the chemist. There are believed to be something like two thousand atoms to the molecule in the red pigment (hæmoglobin) of the corpuscle! These disks, or corpuscles, are formed, mostly, in the red marrow of the bones, and, after serving for a few weeks, they are broken up in the liver or the spleen.

But this is only the beginning of the interest

of the blood. In the drop which we observe under the microscope there are, as we said, myriads of red corpuscles in a yellowish fluid. It was found out some years ago that the serum is quite congenial to its own corpuscles, but that if we mix into it a little of the blood of some animal of a different kind, the serum of the first animal destroys the red cells of the second animal. Thousands of experiments were made,

Warfare in the Body.



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RED BLOOD CORPUSCLES OF MAN.

Each cell or corpuscle is a circular disk, on an average about $\frac{1}{3200}$th of an inch in diameter, and about one-fourth of that in thickness. More than a million will lie on a square inch. The broad faces are not flat, but slightly concave; so the corpuscles are thinner in the middle than at the margin. When seen edge-on they look like rods. Their colour is faint yellowish-red, due to the pigment hæmoglobin, which has a great affinity for oxygen. The mammalian red blood corpuscle does not show any nucleus except in the early stages of development. The white blood corpuscles are larger, nucleated, and irregular. The red blood corpuscles are mostly made in the marrow of the bones and mostly destroyed in the liver and spleen.

and it was found that the degree of action of one kind of blood upon another depended on the nearness or remoteness of relationship of the two animals. If they were nearly related, there was no destructive action. Naturally, the opportunity was soon sought to apply this new test of "man's place in nature," and it was found that his blood mingled amiably with that of the anthropoid apes!

There is a third element in our drop of blood under the microscope, and this is the most interesting of all. Here and there in it, though hundreds of times less numerous than the red disks, there are what are called "white corpuscles," microscopic colourless roundish specks. When we study these specks closely, we find that they behave just like the very primitive microscopic animal known as the *Amœba*. They push out parts of their substance, and glide along. If there are bacteria in the blood, one of these corpuscles may be seen making its way to one of the intruders and slowly folding its substance round it. After the microbe is engulfed, digestion soon follows.

In other words, there is in the blood, besides the army of oxygen-carriers, a great army of defenders against bacteria. Let a tissue be injured somewhere, and the injurious bacteria find a footing and begin to multiply at an appalling rate. We are threatened with disease, if not death. The bacteria may destroy the tissue, or pour poison into the blood. But the "white knights" now gather from all parts to defend the body. They are brought, of course, by the flow of the blood, but they seem to have some sort of chemical sense for bacteria, and they crowd in the particular tissue which is threatened. A great struggle ensues, and the patient's temperature rises to "battle heat." If the white corpuscles succeed in devouring the microbes before they multiply to a dangerous extent, we are saved. But bacteria multiply at a terrible speed, and sometimes they beat the corpuscles and we pass into a perhaps dangerous illness.

Biologists had hardly ceased to wonder at this new romance of the blood when others were discovered. Bacteria produce a poison (or *toxin*) with which they taint the blood. But it was found that the blood produces an "anti-toxin," a chemical for neutralising the toxin; and after years of experiment the anti-toxin was prepared in the laboratory and injected into the blood. It also became possible to help the white corpuscles in the fray, or spur them on to it, so to speak, by preparing a sort of sauce—an *opsonin*, the man of science calls it—from dead bacteria and injecting it into the blood. The opsonin makes the living bacteria more attractive or palatable to the corpuscles, and our "brave defenders" go to work more vigorously. Sir Arthur Keith, in *The Engines of the Human*

Photo: Rischgitz Collection.

HARVEY DEMONSTRATING THE CIRCULATION OF THE BLOOD TO CHARLES I.
(From a Painting after Robert Hannah.)

William Harvey, 1578–1657, a graduate of Cambridge, who studied under Fabricius, the great anatomist of Padua. He demonstrated about 1616 that the blood passes through the body in a "kind of circle"; but he did not know of the capillaries which connect the arteries and the veins. He insisted on experiment as a basis of knowledge, and he made important observations on the development of the chick.

Body, refers to "the immense and movable armies of microscopic corpuscles which can be mobilised for police or sanitary duties. They swarm in the blood stream as it circulates round the body . . . it is extremely probable that one variety of them, if not more, are really errand-boys on their way to deliver messages or parcels, and that the gland masses which are built up in and around lymph channels serve both as nurseries for the upbringing of such messengers, and also as offices from which they are dispatched on their errands."

§ 6

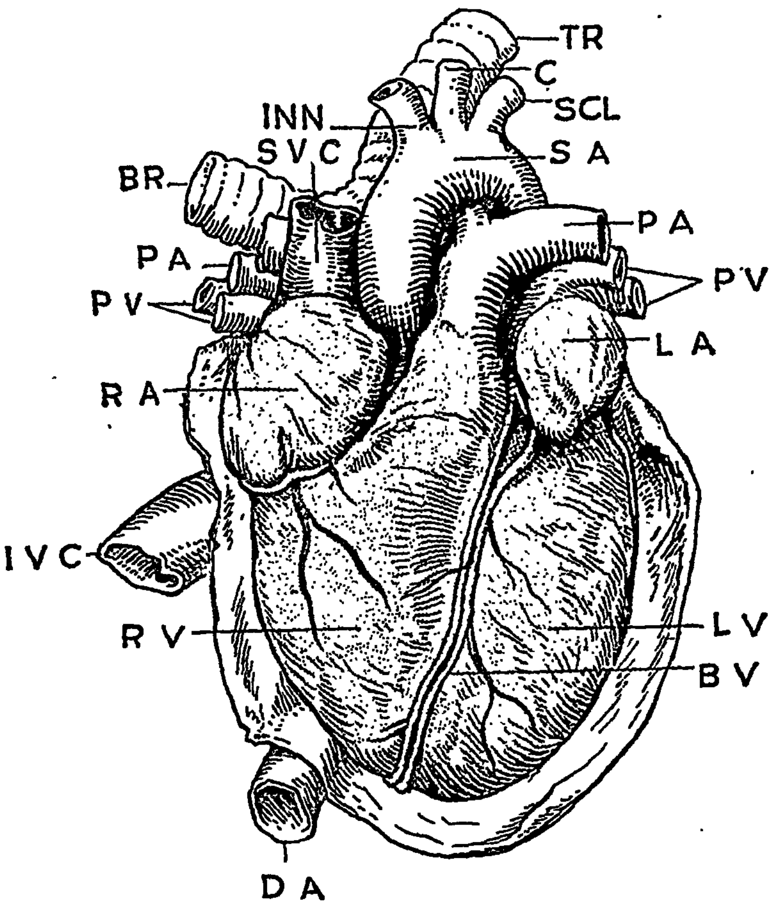
It is clear that the many-sided value of the blood depends upon its regular coursing through the whole body, and we have now to see how this is accomplished.

The Heart.

Until three centuries ago there was not a man in any civilisation who knew anything about this "circulation of the blood." The most learned physicians had the weirdest ideas about the function of the heart and the flow of the blood. Nowadays the essential facts are familiar. The heart, which one feels beating about the lower part of the breast-bone (though drawn a little to the left), is the central pumping-station. From it goes a great tube, or artery, which branches out—much as the trunk of a tree divides into branches, and finally into twigs—until its finest ramifications have carried the blood into the remotest tissues of the body, even into the teeth and bones. There the little twigs turn back, as it were, and become veins, and the veins from all parts join each other and at last bring the blood back to the heart.

In a sense it is as if the fresh-water circulation and the sewage circulation of a great city were managed from the same pumping-station. One set of pipes would convey water to every tap;

another set would bring back the foul water to the pump. The difference is that in the animal body the two sets of pipes join on to each other and form a continuous system. But, obviously, fresh and foul blood must not mix, and this has been secured by the evolution of a heart with the two halves completely separated from each other. We can trace the evolution of the heart by studying it in various types of lower vertebrates. In most reptiles the two halves are still *imperfectly separated*, and "mixed" blood (pure and impure, fresh and foul) goes to the greater part of the body. In the mammals and birds the separation is complete.



THE HUMAN HEART.

There are four chambers, two auricles or receiving chambers and two ventricles or driving chambers. The right auricle (R A) receives the impure blood from the body by two superior venæ cavæ (S V C) and one inferior vena cava (I V C).

The blood is passed into the right ventricle (R V), whence it is driven to the lungs *through the* pulmonary arteries (P A). From the lungs the purified blood returns by the pulmonary veins (P V) to the left auricle (L A).

From the left auricle it passes to the left ventricle (L V), whence it is driven up the systemic arch (S A) to the body. The systemic arch first gives off a right innominate artery (I N N, dividing into right subclavian and right carotid, to arm and head respectively). It then gives off a left carotid (C) and a left subclavian (S C L), to head and arm respectively. It is continued dorsally backwards to form the dorsal aorta (D A), the great artery distributing pure blood to the whole posterior body.

T R is the windpipe or trachea; B R, a bronchial tube carrying air to the lungs; B V, a blood-vessel on the wall of the heart itself.

The heart is a thick muscular pouch—with walls about half an inch at their thickest part in man—which has to drive the blood to the tissues on the one hand, and to the lungs for purification on the other. That is why it has separate halves. Each half, moreover, has a

little chamber for receiving the blood (an auricle) and a larger chamber for pumping it (a ventricle), and valves are cunningly contrived at each opening so that the blood can flow only in one direction when the pump works.

So remarkable is the mechanism of the heart, that we do not yet know what regulates its "beat." There seems to be some mechanism in the heart itself for regulating it. Seventy-two times in every minute, in a healthy and resting man, the chambers draw their walls together and pump out the blood. There are tens of thousands of muscular fibres built so wonderfully into the walls that the chambers can close in from every side, like a man closing his fist, and give the blood a start that will carry it all round the body and back to the starting-point.

It is, of course, a mistake to say that the heart never rests. It rests, and recovers, between each beat. But its function is remarkable. As we said, it beats seventy-two to the minute when a man is resting. But let there be some sudden call for action, and, almost before you get from your chair, the great pump beats faster, as if it knew that the distant muscles and brain had now work to do and must have more blood. When we are sitting still, it throws five pints of blood (a little more than a third of all the blood in the body) into the arteries every minute. During a quick walk the heart pumps seventeen pints a minute; and the man who runs upstairs is asking his heart to pump thirty-seven pints a minute! During even less violent exercise than this, all the blood in the body (about fourteen pints) passes twice through the left ventricle of the heart and all round the body in a single minute.

From the left ventricle, the chief pump, the blood passes into a thick broad tube called the aorta. The elastic walls of this tube expand as the blood rushes in, and then slowly close again, driving the blood onward. In this way, and by the general resistance of the tubes (the arteries), the jerky discharge from the heart is converted into a steady flow after a time. The arteries branch out in every direction, and as they approach the tissues they have to feed they break into myriads of very fine tubelets, often not more than $\frac{1}{3000}$ of an inch in thickness. The wall of the blood-vessel has now to be so thin that the nourishing matter in the blood can flow through it to the tissues, and the waste matter from the tissues can get back into the blood. Even this is a far more complicated matter than is generally supposed. The cells in each tissue of the body must somehow select their own food and oxygen, and even the union of oxygen with carbon in the working muscle does not take place as we find it in ordinary combustion.

At the point where the artery subdivides into the finest tubelets (the capillaries), there is a wonderful apparatus, a sort of "stopcock," for regulating the supply of blood. Muscular fibres are coiled round the artery, and, as the artery enlarges or contracts, the supply of blood to that particular tissue is increased or lessened. When you sit down to a meal, for instance, the stopcocks are opened

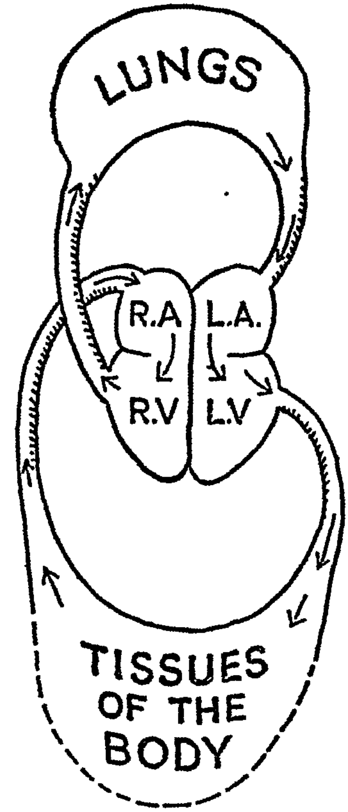


DIAGRAM OF THE CIRCULATION OF THE BLOOD THROUGH THE BODY.

Seventy-two times a minute the heart beats; that is to say, its muscular walls contract. Each half of the heart consists of two chambers: the auricle, which receives blood from the big veins, and the ventricle, which receives blood from the auricle and pumps it into the big arteries. Between the right and left sides of the heart there is no direct communication. Aerated blood is collected from the capillaries of the lungs and conveyed by the pulmonary veins to the left auricle, whence it passes to the left ventricle. Thence it is pumped into the great artery, the aorta, whose branches distribute it to every part of the body. Having given up much of its oxygen and nourishment to the tissues needing them, the blood is collected and conveyed by veins to the right auricle. From there it passes to the right ventricle, which forces it through the pulmonary arteries to the lungs, where it is aerated and again travels to the left side of the heart, ready to be again circulated. It will be noted that arteries are blood-vessels leaving the heart, while veins are blood-vessels returning to the heart. The arteries carry pure blood, except in the case of the pulmonary arteries to the lungs. The veins carry impure blood, except in the case of the pulmonary veins from the lungs.

full to your digestive organs and partially closed against your muscles and brain. When you stand up and move about the room various muscles have to work, and the cocks are duly turned on to them. When your muscles need all the blood they can get, your brain and digestive organs get less. When you stand erect for some time, the regulative system has to see that blood does not accumulate in your legs at the expense of your head; but if you overdo it—if you stand long in a close crowd or a stuffy room—even this admirable system breaks

A Wonderful Apparatus.

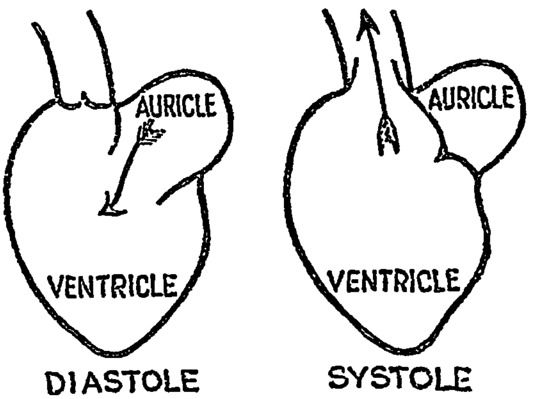


DIAGRAM ILLUSTRATING THE VALVES OF THE HEART.

During the period of contraction (systole) of either of the ventricles the valves which guard the opening of the big artery are open, whilst the valves at the gateway between auricle and ventricle are closed, thus preventing blood from being forced back into the auricle. During the period of relaxation (diastole) of the ventricle, the valves of the artery are closed and those between auricle and ventricle are open, allowing blood to flow freely from auricle to ventricle, but preventing back-flow from the artery.

Both auricles contract at the same time. Then both ventricles contract simultaneously. Then there is a short pause. Each complete cycle, including the pause, is a "beat"; and in a healthy adult the heart beats about seventy-two times in a minute.

down, and your brain, which is particularly sensitive about oxygen, runs short of blood. You "faint."

Here again science has only made a great discovery to be confronted with a mystery. We know that there are nerves from the muscles of the arteries to the spinal cord, and that the stopcock we have spoken of is regulated by a reflex nervous message from the cord; but how these unconscious elements of the human mechanism work so perfectly together we do not know. When we remember how densely ignorant of all these things men were only a few generations ago, we may be sure that much will be discovered by our children and grandchildren.

Every year, indeed, brings new discoveries of a remarkable kind. We have already noticed that certain chemicals called "hormones," of which we shall speak more fully immediately, are produced in various structures (ductless glands) of the body, and "posted" in the blood, as it were, for a distant organ. One of these "hormones" comes into play in connection with the blood. When a man is setting about some prolonged and strenuous exercise, nerve-messages go to stimulate certain glands near the kidneys called the adrenal or suprarenal glands. They supply one of these chemicals (*adrenalin*) to the blood, and it passes round the circulating system until it reaches the small arteries. It closes the cocks and shuts down the supply to organs which are not at the time required to be active, and thus ensures a fuller supply to those organs which are called into strenuous exercise.

When the blood has passed through the tissues—given up its nutriment and received the waste carbonic acid gas and the soluble nitrogenous waste—the blood turns back towards the heart. It passes into a new set of fine tubelets or capillaries, and these unite in the veins. The veins have thinner walls than the arteries, as there is now less pressure, but they have a remarkable series of valves along their course. The blood cannot flow back—cannot go wrong. You can actually trace one or two of the valves on the veins of your arms if you try to force the blood back to your fingers. Little knots stand up here and there. So the blood courses steadily back and is poured into the opposite side of the heart to that from which it started. It enters the right auricle, and passes on into the right ventricle; and the next beat of the heart sends it to the lungs, where it gives up its carbonic acid and gets a fresh supply of oxygen.

§ 7

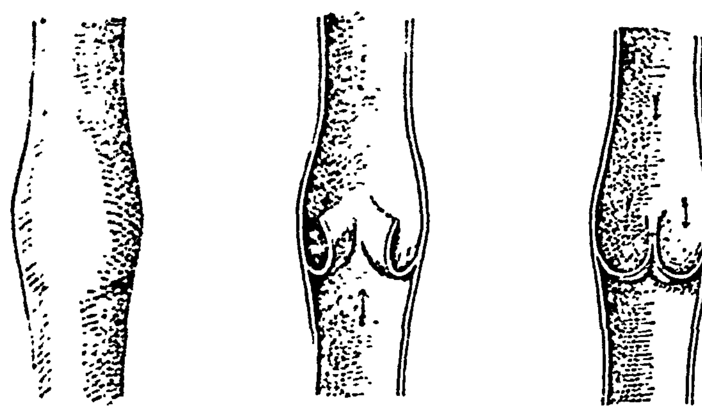
How and Why we Breathe.

The blood has many functions. It takes fluid food to the organs and, in its red corpuscles, it carries oxygen. It has also to bring away from the organs the waste products of their activity, the carbonic acid (carbon dioxide), which is got rid of in the lungs, and the soluble nitrogenous waste,

which is got rid of by the kidneys. The work that is done in the various organs—such as the muscles, nerves, and glands—may be roughly compared to the work done in a simple steam-engine. Fuel must be supplied; then oxygen (the essential element of air) must be supplied to unite chemically with the fuel and convert the energy which is locked up in it into heat and active work. The stomach supplies the fuel. The lungs, like the blacksmith's bellows, supply the draught of oxygen. If we do not forget that in the animal body the chemical action is far more subtle and indirect than in the furnace, this may be taken as a useful simple view of what goes on.

Let us follow the draught of air into the lungs and the blood. We saw that, for the food to become available to the tissues, the blood-vessels have to become finer and finer until at last their walls are so thin that the nutritive material can pass through them. It is the same with the air-passages through which we breathe. The air enters by the nostrils; we will suppose, at least, that the reader is sensible enough to breathe always through the nostrils, and teach his children to do the same. In the nose there is a warming chamber, richly supplied with blood (and the supply automatically increases in cold weather), and there is a sort of sieve or filter (the hairs in the nostrils) for "screening" foreign bodies from the air. Dry air is also moistened in the nostrils. There is a mucous membrane in it which is most useful if you treat it reasonably; but if you treat it unreasonably—if you pack yourself with others into a moist, stuffy, unventilated railway-carriage or small room—it will get gorged with blood and "boggy," and offer a good field for certain microbes, and—you will have a "cold in the head."

Behind the root of the tongue the air-way crosses the food-way and enters the windpipe or trachea. At this point there is the customary "door," automatically opening and shutting; and behind this delicate folding-door are the "vocal chords" which we use for speech. The windpipe divides at its base into the two bronchial tubes, one for each lung, and there are ingenious arrangements for dealing with dust or microbes that have got past the sentinels in the nose. There is a coat of mucus to intercept them (as a flypaper does flies), and there are countless microscopic lashes or cilia which bend and straighten rhythmically, beating towards the entrance, and thus gradually push out the intruder. If certain kinds of dangerous microbes settle on them, the glands pour out large quantities of mucus, and your lungs automatically blow it out at times—you have a "cold" and a "cough."



A. B. C.

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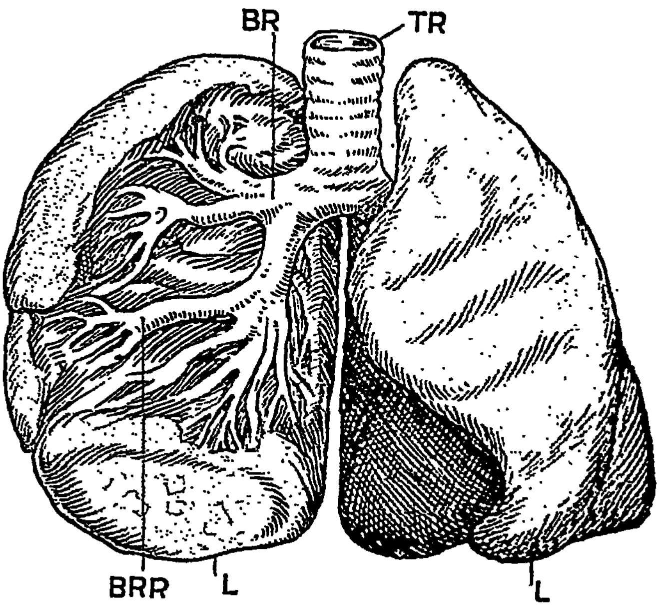
A, a swelling on a vein, indicating the presence of a valve within it. B, the vein laid open, showing the valves partly open: blood flowing in the direction of the arrow will have free passage between the valves. C, showing the valves shut: blood forced backwards in the direction of the arrows will find the valves closed against it.

In the lungs themselves the bronchial tubes branch out into numbers of fine tubes as the arteries do, and each tube ends in a score or more of little air-chambers. There are about six millions of these minute chambers (each about $\frac{1}{10}$ of an inch long) in the two lungs, and they are formed so as to give as much surface as possible. If we could open them all out and piece them together, we should have a total surface a hundred times larger than our skin. This is the wonderful contrivance evolved for bringing a large body of air into almost direct contact with the blood fifteen times a minute or

more. In a deep breath we can take in a whole gallon of air, and even a normal breath takes in two quarts.

But who attends to the working of this wonderful bellows while we are sleeping or are concerned with other matters? It is, of course, another of those automatic mechanisms which have been formed in the animal body during millions of years of trial and sifting. The lowest part of the brain, a part called the *medulla oblongata*, includes a nerve-centre which is sensitive to

Nerve Messages.



THE WINDPIPE AND LUNGS OF MAN. (From a specimen.)

TR, the trachea or windpipe, supported by gristly rings. It divides into two bronchi (BR) entering the lungs (L). There they break up into finer and finer bronchial tubes or bronchioles (BRR), ending in little dilatations which are divided into chambers called "air-cells." On the walls of these the interchange of gases takes place. To the left side, as diagrams go, the lung is seen intact; to the right, partly dissected.

the carbonic acid in the blood and, stimulated by this, sends automatic messages to the muscles of the ribs and the midriff, or diaphragm. At each intake of breath twelve pairs of muscles work harmoniously in expanding the chest, and then other muscles pull the "bag" together again and expel the air. But how can the air extract the carbonic acid from the blood in so short a space? All such difficulties are provided for in the body-machine. You breathe out only a fifth of the air in your lungs every time. The little air-chambers automatically close if, by a strong effort, you try to empty your lungs. The exchange of gases is going on all the time. If, on the other hand, the muscles are working hard, and need more oxygen, the increased carbonic acid in the blood stimulates the medulla, and nerve-messages from it rain upon the lung-muscles until you "pant for breath."

A man or woman engaged on sedentary work gets into a way of using the lungs to only about a tenth of their capacity. You understand the pale scholar and the anæmic girl in the cash-box. They provide too little oxygen, and the blood will not provide red corpuscles which are not needed. If such people will go for a good swinging walk, in air that is rich in oxygen, the blood will stream through their medulla, the nerve-centre at the base of the brain, and the lungs will open out.

The real "breathing" is, of course, deep inside the body. The little air-chambers have walls almost as thin as soap-bubbles, and a rich supply of similarly thin blood-vessels (capillaries) outside them. Through these thin walls the red corpuscles somehow extract the oxygen from the air, and the blood also gives off the carbonic acid. Then the blood streams back to the left chamber of the heart to be pumped through the body in the way we have described. When this blood finds itself in the thin-walled capillaries amongst the organs of the body, the red corpuscles yield their oxygen, and the blood returns to the heart with a new load of carbonic acid.

We have seen that this union of oxygen and food in the tissues may roughly be compared to what goes on in a steam-engine. It enables the organs to work—to do the work we describe here—and it produces heat. And in connection with this heat we employ, all our lives, wonderful mechanisms which even modern science has only partially mastered.

The blood must be kept at a temperature of (in a normal human body) about 98·4° F. When the air sinks very low in temperature, we shiver,

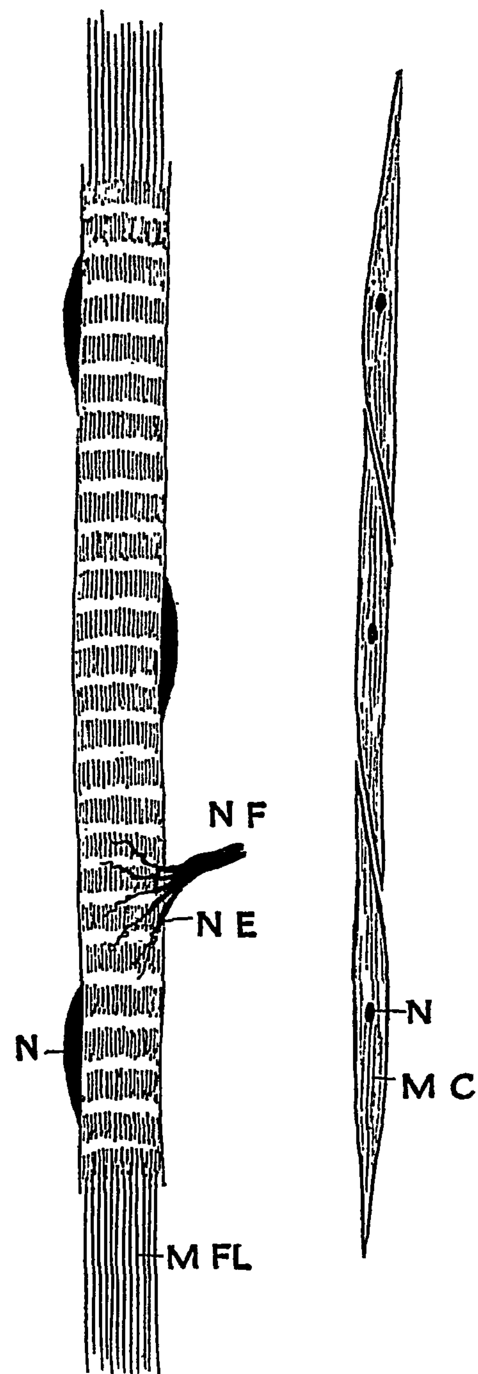
or stamp our feet, or rub our hands. The shiver is an automatic warning to take exercise, to increase the combustion in the muscles. When, on the other hand, the outside temperature rises too high, we get the stopcocks of our arteries, which are tightened on a cold day, now opened wide, to let the blood's heat escape by the skin. If this does not suffice, automatic messages go from the nerve-centres to the millions of sweat-glands in the skin, and we "sweat." To raise the temperature of the watery fluid so much heat has had to be extracted from the blood. If the air is dry as well as warm, this mechanism is generally sufficient, but if we are in a "moist heat"—everybody knows how much worse it is than dry heat—the evaporation through the skin is checked, and the temperature of the blood rises until it may be too much for our brain. Even cold moist weather is trying. Our vitality is lowered in meeting it, and the cold-microbes get their chances to invade the body.

A wonderful mechanism surely! But there seem to be unintended effects at times of these ingenious devices. Take the "crimson flood" on a girl's cheek at some ugly word, or some word of praise, or some consciousness of guilt. The stopcocks to the capillaries in her cheeks are opened wide, but we can hardly suppose that some nervous reaction was evolved for that purpose. Sudden paleness is more intelligible. The cheek blanches in the face of danger, because the stream of blood has been directed to the brain and muscles that may have to meet the situation, and such temporarily useless organs as the cheek have the supply cut off.

§ 8

The Large Machines of the Body.

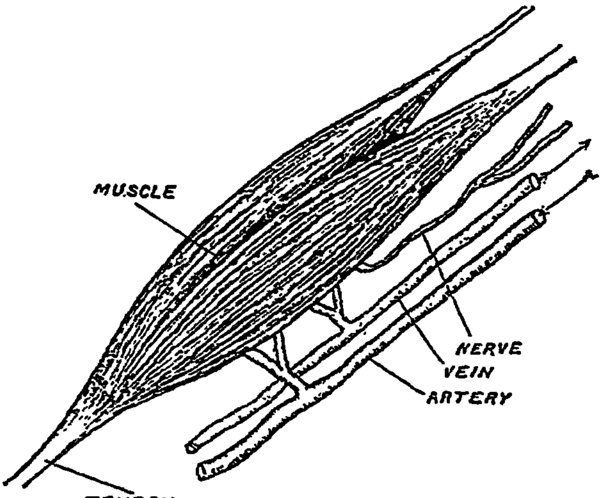
We may seem so far only to have concerned ourselves with organs which exist for the sake of other organs. That, in point of fact, is the nature of every organ in the "organism"; and indeed, it would be at least equally correct to say that bones and muscles, which one naturally thinks of as forming the greater part of the body, exist very largely for the purposes of digestion and respiration. Nutrition and reproduction are the oldest functions, the original functions, of the animal body. The elaborate skeleton, with its masses of muscle, has evolved to protect and minister to these fundamental activities.



A

A. A striped or striated muscle-fibre, quickly contracting, showing alternate dark and light bands. It is built up of very delicate fibrils (M FL). It is stimulated by a nerve-fibre (N F), which divides into an end-plate (N E) on the contractile substance. A striped muscle-fibre is due to the great elongation of a cell, with multiplication of nuclei (N), or to a fusion of elongated cells.

B. Three smooth or unstriped muscle-cells (M C), elongated spindles, dovetailed into one another, each with a nucleus (N). There may be longitudinal fibrillation. Smooth muscle-cells are slowly contracting. They occur in such situations as the wall of the food-canal, the wall of the bladder, the wall of the arteries; and abundantly in sluggish animals, such as sea-squirts.



Reproduced by permission from Keith's "The Engines of the Human Body" (Williams & Norgate).

A DRAWING OF THE BICEPS OF THE UPPER PART OF THE RIGHT ARM, SHOWING ITS TENDON, ITS BLOOD-VESSELS, AND ITS NERVE.

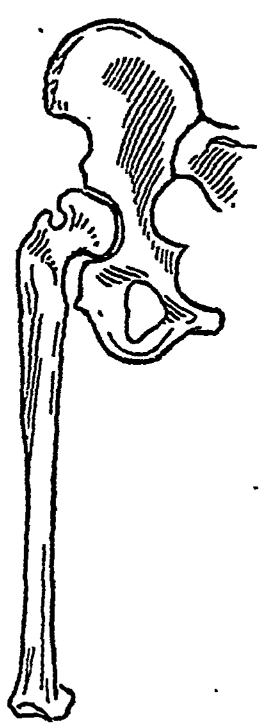
A tendon or sinew fastens a muscle to a bone; the artery brings oxygen and food-material for the muscle; the vein carries away carbon dioxide and waste; the nerve conveys the stimulus which provokes the muscle to contract. The biceps lies along the upper arm or humerus; its upper end is connected by two tendons with the shoulder-blade or scapula; its lower end is connected by a tendon with the radius, one of the bones of the lower arm; when the biceps contracts, becoming shorter and broader, as we can feel it doing, it raises the lower arm nearer the upper arm.

Of the distribution of the two hundred bones and two hundred and sixty pairs of muscles which form the great bulk of the body little can be said here. A catalogue of the bones would be a list of unfamiliar terms; and a catalogue of the muscles would be almost an essay in Greek. It is in the development and minute structure of bone that modern physiology is chiefly interested. As is now generally known, the body begins its existence as a single cell—a microscopic speck of living matter surrounded by a membrane—and the development of the body is due to the repeated and rapid multiplication of this cell (the fertilised ovum or egg-cell), until countless millions are formed. It is a "cell-state": a commonwealth of millions of living, active units bound together into a harmoniously working organism.

As this "protoplasm"—the jelly-like matter which composes cells—is soft, the beginner may wonder how it can build up such structures as teeth and bones. To understand this, as far as we do understand it at present, we have to remember that, as the cells of the body multiply from the original egg-cell, they also separate into different classes. We get muscle-cells, nerve-cells, bone-cells, gland-cells, and so on; and they differ remarkably in structure from each other.

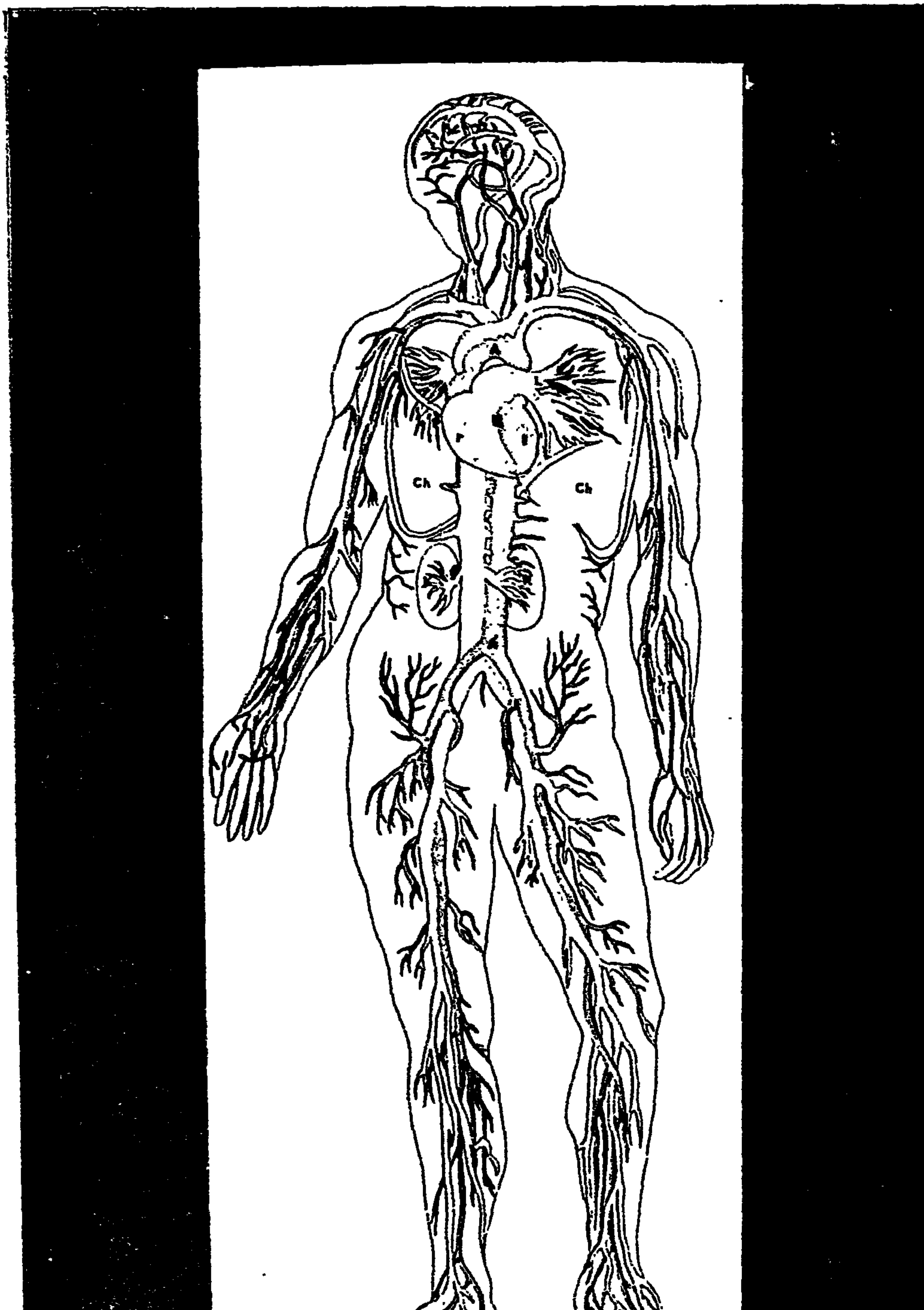
One contingent of these cells consists of the "bone-builders," and long before birth they begin to construct the supporting framework of the body. It is, of course, not bone at first. Frames of cartilage preceded bony frames in the course of racial evolution, and a cartilage-frame goes before bone in the development of the individual body. When the time comes, the bone-builders extract the lime-salts which have got into the blood with the digested food, and they use these in building up the bones. Sir Arthur Keith tells us that there are two million of these bone-builder cells at work in the thigh of a new-born baby, and that the number rises later to a hundred and fifty millions. They make the bones solid, then they change the interior into the light but strong texture with which everybody is familiar.

How is it that we feel no creaking, no jarring, or friction, of the two hundred and thirty joints by which our bones play upon one another? Here is another ingenious contrivance. A layer of cartilage remains over the end of each bone. It is dense, very elastic, and always well lubricated by one of the many remarkable



THE HIP-JOINT.

The thigh-bone or femur is shown with its rounded head fitted into the socket (acetabulum) of the hip-girdle, which, in turn, is fixed to the sacral region of the backbone. This hip-joint is a good example of a "ball and socket" joint with a deep cup; the shoulder-joint is on the same principle, but with a shallow cup. The head of the thigh-bone plays in the cup furnished by the hip-girdle and has considerable freedom of movement, but much less than the arm, which plays in a shallow cup.



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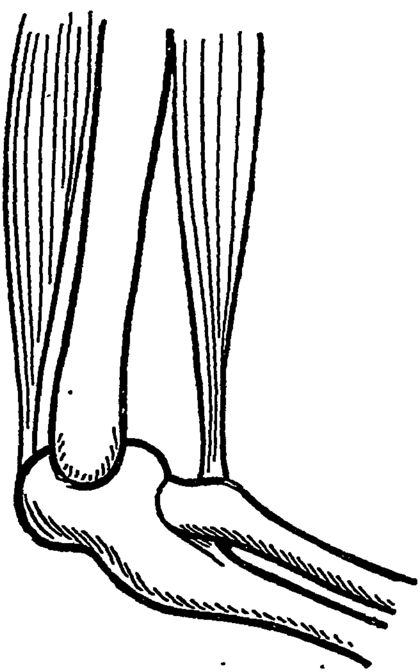
DISTRIBUTION OF THE MAIN BLOOD-VESSELS OF THE HUMAN BODY

The Arteries are shown in red, the Veins in blue. H, the heart; *l*, left side, *r*, right side. Arising from the left ventricle of the heart is the main artery, the dorsal aorta (A). The letter is put at some distance from the heart, near where the vessel gives off the branches (in red) for the head and arms (carotid and subclavian arteries), and at the point where it arches backwards and downwards to pass through the chest and abdomen, till at A′ it gives off branches for the legs. The veins are represented running alongside of the arteries. Beside the dorsal aorta runs the great vein—the inferior vena cava—going to the right auricle. At K is represented the position of the kidneys and their renal vessels. L represents the pulmonary veins of the lung, the only veins with

automatic lubricating systems of the body. The cartilage cells themselves in this case are converted into lubricating fluid when they die!

The muscular system which moves the bones is the red flesh with which we are familiar in the butcher's shop. Everybody who has carved a joint, and knows the importance of cutting "against the grain," is aware that one of these large muscles of the ribs or limbs of a cow consists of muscular fibres packed closely in bundles. There are 600,000 fibres in a single muscle of man's arm, the biceps. Each fibre is composed of many fibrils, the seat of that power of contractility which we very little understand. The body-machine is still full of problems and mysteries for us. Three hundred years ago the courageous anatomists of the later Middle Ages began to make out the structure of the organs. Later came a generation which dissected the organs into tissues. Later still, as the microscope improved, the tissues were dissected into cells, and the whole life of the organism was resolved into the co-operative life of millions of these units. But we now know that the secrets of the life of the cell lie partly in the molecules which compose the cells, and these are beyond the range of the most powerful microscope. We must wait and be grateful for what we know. Science never rests. On the very day on which I am writing this page the press announces the discovery of a new microscope, which takes us at a bound deeper into the mysteries of living nature!

Meantime, science has shown us that the muscular system is an automatic living mechanism of the most wonderful kind. To every muscle the arteries bear their streams of food and oxygen, the muscle-cells select their diet, and the veins take away the waste-products. On every muscle there are also the fine endings of some nerve from (generally) the spinal cord, and at the proper moment a discharge along the nerve causes the whole mass of the cells or fibres in a muscle to contract simultaneously and lift the bone to which the muscle is attached. The nerve-impulse itself is slight. It is merely like a match set to the great energy stored up like powder in the muscle. But when we remember the number of muscles needed for a single harmonious action—we bring fifty-four into play at each step in walking, and there are about 300 muscles concerned when we walk—the delicacy of their adjustment, the precise degree of action needed in each, we cannot but marvel at the ceaseless regularity and correctness of this unconscious play of muscle and nerve and nerve-centre. We can say only that it is broadly and beautifully illuminated by the story of evolution—a slow advance during millions of years, during which every individual with a defect is sifted out and every improvement means longer survival in the struggle for life.



THE ELBOW-JOINT.

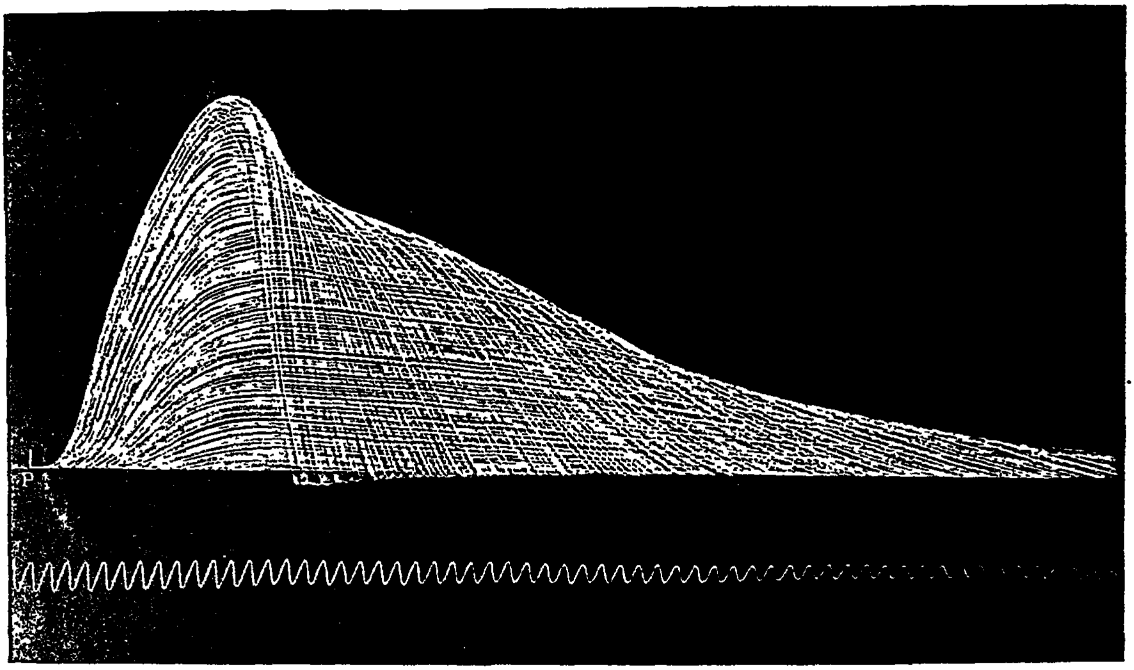
The elbow is a fine example of a simple hinge-joint. The lower end of the humerus works on the upper end of the ulna, which bears an elbow process or olecranon, which prevents the arm being bent back The biceps muscle, which is fixed above to the shoulder-blade, is inserted below on the radius, and bends the arm when it contracts. At the back of the elbow-joint is seen the triceps which straightens the arm when it contracts.

§ 9

THE NERVOUS SYSTEM AND THE BRAIN-CENTRE

Most wonderful of all structures in the body-machine, and most difficult to understand, is the telegraphic system—the nerve-threads or "wires" and the central stations in the brain, the spinal cord, and certain other clusters of nerve-cells. A unified cluster of nerve-cells is called a ganglion

The Nervous System.



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INFLUENCE OF FATIGUE ON THE CONTRACTION OF A MUSCLE.

The muscle is made to write a series of curves, P being the point of stimulation; the lower separate wavy line is the time-tracing, the waves indicating hundredths of a second. The point is this: For a time the contractions improve, becoming more and more vigorous, with higher and higher steep curves. But by and by the contractions get less and less vigorous; they take longer and longer; the curves get flatter and flatter. Finally the muscle ceases to contract at all.

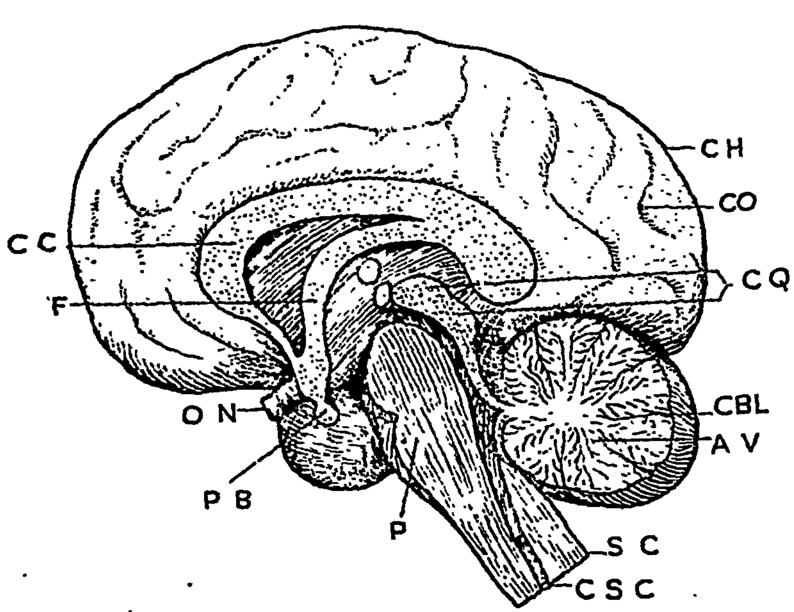
or nerve-centre. In the simplest forms of life there is no nerve, no muscle, no mouth or stomach. The microscopic unit is one single cell—a bit of jelly-like living matter enclosed in a more or less definite membrane. Each and every part of it digests food, contributes to the movement, and is sensitive to the surroundings. In the course of evolution there arose larger organisms with *bodies*, with millions of cells bound together in harmony, *showing division of labour*. Some cells specialise on nutrition, some on reproduction, some on locomotion, and so on. Some of these cells specialise on sensitiveness, and thus arise nerve-cells. Then some specialise on one particular kind of sensitiveness, and there appear patches or pits in the skin, one sensitive to light, another to smells, and so on. Further advance unites these various centres by nerve-fibres, and at last a central telegraph station, a long tract of nerve-matter, connects up the various sense-centres and the muscles and glands. When a backbone is evolved, the main tract of central nerve-stations is enclosed in it; and, as life advances, the upper part of this "spinal cord" swells into a brain and is protected by a skull.

This interesting story of the evolution of the brain and sense-organs deserves to be told at greater length, but this slight outline may serve at present for our understanding of the essential nature of the nervous system. There is, as we said previously, a postal system and a telegraphic system in the body. Certain organs discharge certain chemicals (hormones) into the blood, and the blood delivers them to distant organs which are thus set to work. Obviously, this postal system would be too slow for the purposes of ordinary life, and so the telegraphic system is richly developed. Suppose that in bathing you tread on a sharp stone. In a fraction of a second a nerve-thrill flashes from that part of your foot to a certain centre in the spinal cord, and a return thrill causes the muscles of the leg to contract, thereby jerking back the foot. In an animal far down in the scale like the octopus this nerve-message goes at about eighty inches a second; in the frog the speed has worked up to ninety feet a second; in man it reaches about four hundred feet a second.

In the case of man the nerve-message often goes on to ring a bell in the brain, as it were—to announce itself in consciousness—but the greater part of the body-machine is run, as we have seen, by automatic action, and we will first master this. We have spoken repeatedly of "reflex action." We mean by this nervous action without conscious effort. The message that goes to the brain or spine is automatically "reflected," along a different "wire," to the muscles or glands. When a piece of dust blows against your eyeball, one nerve sends some sort of thrill to a centre in the brain. Within a very small fraction of a second this message passes through a nerve-centre in the brain, and another thrill comes back to the muscles of the eyelids. Nearly the whole body is connected up, generally through the spinal cord, by an automatic nervous machinery of this kind. For the muscles of the head and face the nerve-centres are in the brain.

The nerve-cells (or neurons, as they are often called) have a cell-body and outgrowing fibres or "wires." Each cell has two or more fibres running out of it, and these in most cases end in brushes of still finer threads. The nerve-cells are, therefore, particularly suitable for communicating with each other. In the brain and spinal cord especially each cell runs into a little brush or tree of fine fibres, and they interlock with each other. In the nerves that carry messages or commands to the muscles and glands many long fibres are bound up into bundles by a sheath. Inside each fibre there is a mysterious central channel, the axis cylinder, probably of a liquid nature.

What the real nature of a nerve-thrill is we do not yet know. It is accompanied by electricity, but it is not itself an electric wave, for such a wave would travel more than a million times faster than the nerve-message does. The nerves are also peculiar in the fact that they never get tired (as long as they are well supplied with oxygen), and physiologists have not been able to discover any definite chemical change in them. Even the production of carbon dioxide is



SECTION OF A HUMAN BRAIN.

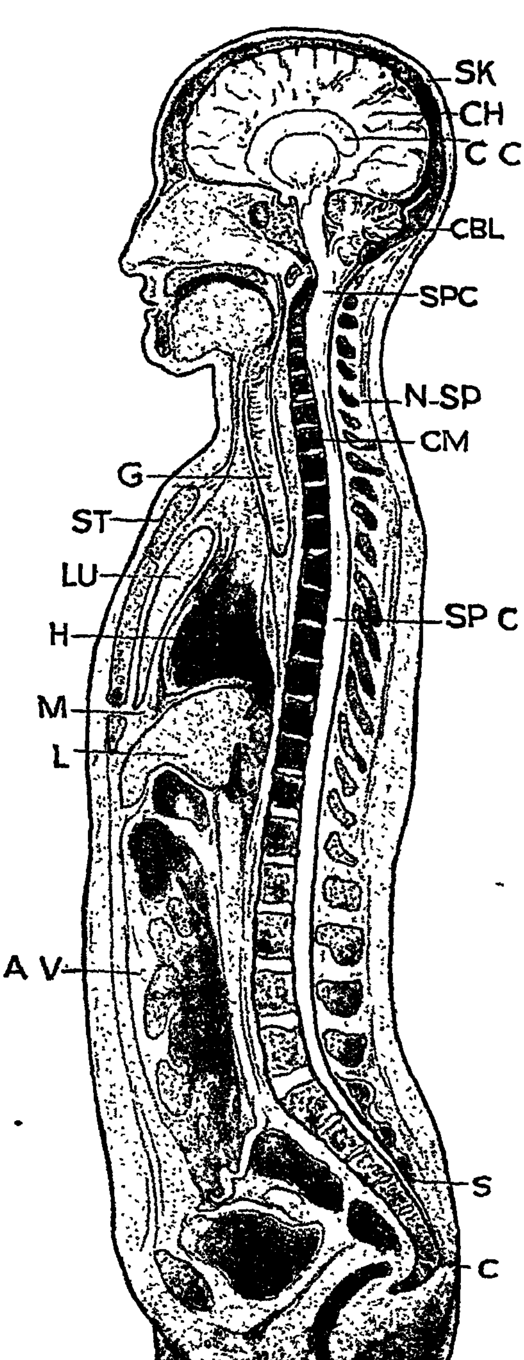
Nerves entering the brain. F is a longitudinal bridge of fibres, called the fornix.. It makes the roof of the optic thalami region, or third ventricle. Behind the fornix are seen two transverse commissures cut across. C Q, the corpora quadrigemina or optic lobes. C H, the fore-brain or cerebral hemispheres, showing internal indications of convolutions (C O).

CBL, the cerebellum, with an internal pattern (A V) called the arbor vitæ. This is due to the folding of the nervous tissue into a number of lamellæ, which give off secondary plaits.

S C, the spinal cord. C S C, the cerebro-spinal canal continued down the centre of the spinal cord.

P, the pons Varolii, a bridge forming a sort of transverse floor to the cerebellum. Behind P is the "bulb" or medulla oblongata.

P B, the pituitary body, a nervous and glandular body growing down from the floor of the optic thalami region, or third ventricle. O N, the optic nerve.



VERTICAL SECTION THROUGH THE HEAD AND TRUNK OF THE HUMAN BODY.

SK, the skull; C H, the cerebral hemispheres of the brain; C C, the corpus callosum, a bridge of nerve-fibres binding the cerebral hemispheres together; CBL, the cerebellum. SP C, the spinal cord; N SP, neural spines of the vertebræ; C M, a centrum or body of a vertebra; S, the sacral vertebræ fused; C, the coccyx, a fusion of post-sacral vertebræ; A V, intestine and other abdominal viscera; L, the liver; M, the muscular midriff or diaphragm, separating the abdominal cavity from the chest cavity; H, the heart; LU, the lung; ST, the sternum or breastbone; G, the gullet or œsophagus. From a specimen.

questionable. Sleeping or waking, the wires are always alive, yet physiologists have not found that any heat is produced in connection with their activity.

The Brain-centre. It is otherwise with the masses of nerve-cells which make up the great brain-centres. Everybody knows that these grow tired, and must have a period of rest and recovery. Sleep is, however, still a puzzling phenomenon, and no theory of it can be regarded as satisfactory. All that physiologists are generally agreed upon is that the blood-supply to the brain is checked, and this lessening of the supply of oxygen (as to which the brain is particularly sensitive) lowers the vitality of the organs of consciousness. About the end of the first hour of sleep (which is the real "beauty-sleep") the brain-life is entirely suspended, and the blood is busy feeding the tired muscles. Some hours later more blood seems to return to the brain, and we get partial consciousness, uncontrolled by intellect, in the form of dreams. In a few individuals there may be, instead of a partial return of consciousness, an awakening of the power of automatic response to stimulations. They are apt to "walk in their sleep."

Our knowledge of the brain is now a special and formidable branch of science; it will be referred to later when we come to deal with Mental Science.

"In some way that we do not understand, our personality is more bound up with our nervous system than with the rest of our body. Our quickness or slowness, alertness or dullness, cheerfulness or gloominess, reliability or fickleness, good-will or selfishness, are wrapped up—in our ordinary life inextricably—with our very wonderful nervous system. Some people believe that our inmost self uses the nervous system as a musician uses a piano, and compare the disorder of mind illustrated in the delirium of fever, or the decay of mental vigour in the aged, to disturbances or wear and tear in the instrument. Others think that the inner life of consciousness—feeling, thinking, and willing—is one aspect of our mysterious living, and that the physico-chemical bustle that goes on in the nervous system is the other aspect of the same reality. The two aspects are inseparable, like the concave and the convex surfaces of a

dome; but no metaphor is of any use, the relation is quite unique.

"This is one of the oldest of riddles, and Tennyson made 'The Ancient Sage' say:

'Thou canst not prove that thou art body alone,
Nor canst thou prove that thou art spirit alone,
Nor canst thou prove that thou art both in one:

For nothing worthy proving can be proven,
Nor yet disproven.'

"Yet three things seem to us to be quite certain: (1) Our nervous system is a scientific actuality that can be measured and weighed; it is complex beyond our power of conception, if only because of the millions of living units which it includes; it is the seat of an extraordinary activity which baffles the imagination. No theoretical view can stand that is subversive of the fundamental reality of our nervous system. (2) Even more real, however, if there are degrees of reality, is our inner life of consciousness, our stream of thoughts and feelings, desires and purposes. It is our supreme reality, for it includes all others, and no theoretical view can stand that is subversive of this reality. (3) But the third certainty is that organism and personality, body and mind, nervous metabolism and consciousness, are in the experience of everyday life interdependent. If it is a relation, there is nothing to which we can compare it; if it is a unity, it is equally unique. We are mind-bodies or body-minds; sometimes we feel more of the one, sometimes more of the other."[1] That, however, as we have seen, will form the subject of a later chapter.

We may note here that it is a popular fallacy to suppose that all the contents of the skull are concerned with thought and feeling, or that a large head means a large capacity. The bulk of the matter in the cranium has nothing to do with thought. It is only a very thin rind or cortex of nervous matter, about a ninth of an inch thick on the average, covering the fore-part of the brain (from the top of the head to the base of the forehead) which is the organ of consciousness. But this precious cortex is an intricate structure made up of 9,200 million nerve-cells, and it is in man folded and creased so as to pack as much surface as possible within the limits of the human skull. Round this central area are the nerve-centres for controlling the muscles of the head, face, eyes, tongue, and the like; and the centres for receiving the reports of the eyes, nose, and ears are also in the brain. In a man who weighs 150 lb., the nerve-cells of the brain-cortex would weigh about $\frac{1}{5000}$ part of the total, but this small part controls the whole.

At the back of the head is the cerebellum, or "small brain": the chief centre for co-ordinating the movements of the muscles so as to produce harmonious action. If it has been injured in a bird or a dog, the animal can no longer stand up or maintain a balance of movement. All day long the cerebellum must be receiving countless messages from all parts of the body and directing our three hundred muscles to co-operate. It is entirely automatic, yet no central telegraph station in the world is so busy or so accurate. It also in some way maintains the tone of the muscles.

Below the cerebellum is the medulla, which, as we saw, is the organ for controlling the muscles of the chest that cause breathing. It has,

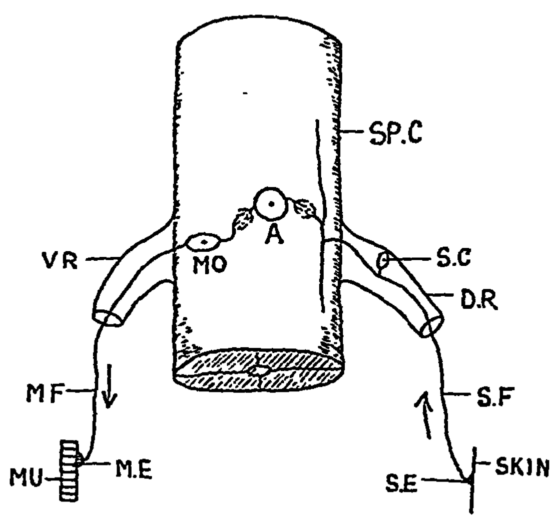


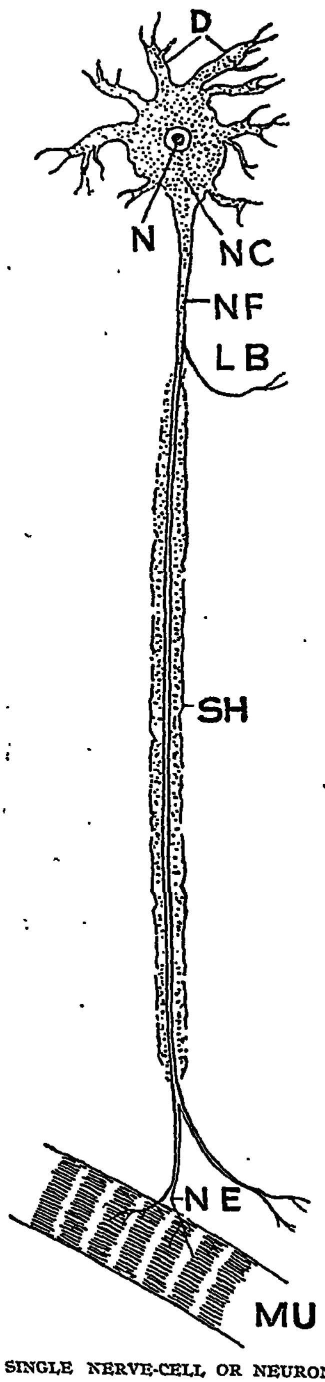
DIAGRAM ILLUSTRATING REFLEX ACTION IN MAN OR ANY BACKBONED ANIMAL.

From a sensory nerve-ending (S E) in the skin, a stimulus passes up a sensory nerve-fibre (S F) to a sensory nerve-cell (S C) in the spinal ganglion of a dorsal or afferent root (D R) of a spinal nerve. The fibre, continued from the sensory nerve-cell, divides in the spinal cord (SP C), and the message passes on to an associative, intermediate, or internuncial nerve-cell (A). Thence it is shunted to a motor nerve-cell (MO), from which a command passes down a motor nerve-fibre (M F), issuing by a ventral or efferent root (V R) of a spinal nerve. The motor nerve-fibre ends in a nerve-plate (M E) on a muscle-fibre (MU), which is stimulated to contract.

[1] Professor J. Arthur Thomson, *The Control of Life*.

however, much more work to do than this. It has some control of the heart and blood-vessels, and it influences movement in the alimentary canal from the salivary glands to the small intestine. We must remember that these hind-parts of the brain are the oldest. The cortex—the nervous matter connected with mental life—is a later acquisition.

And the oldest part of all is the long cord of nerve-cells which is enclosed in the spinal column. Along this are the various centres for working automatically the great muscles of the trunk and limbs and abdomen. Pairs of nerves leave it at intervals, and all day long these are receiving messages and issuing orders. It has an extraordinary power of automatic learning. Watch the baby learning to adjust its muscular actions to its desires or feelings, or a girl learning tennis or typing. In a short time the machinery will react promptly and perfectly to the stimulus. It is through the spinal cord that the brain can influence movements which are usually automatic.



A SINGLE NERVE-CELL OR NEURONE.
(After Stöhr.)

N is the nucleus of the cell; N C, the central cell-substance or cytoplasm. The nerve-cell communicates with others by means of fine protoplasmic branches or dendrites (D). It gives off a nerve-fibre (N F) to a muscle (MU). This fibre has as its essential part an axis cylinder or core, surrounded by a medullary sheath (SH) of a fatty material; and outside this there is a clear membrane called the neurilemma. It will be observed that the medullary sheath is not developed at the origin or at the end of the nerve-fibre. A lateral branch of the fibre is shown (L B) and the ending (N E) on the muscle.

We cannot discuss here how far the bodily features may serve as indices of mental character, whether the face, the eyes, the shape of the head, or the hands—an interesting chapter on the subject will be found in Sir Arthur Keith's little book, *The Human Body*. There is no correspondence, he tells us, between the functions of the various parts of the brain, so far as we yet know them, and the overlying parts of the head to which "phrenologists" have assigned definite functions. Some day we may be able to add to our knowledge of a man's character derived from observation of the expression of his face, his words and actions. "The day may come when by looking at the brain, or even at the skull which encloses it, we shall be able to tell the capabilities of a child or a man, but we have not yet reached that point." Neither is it true that the lines of the palm of the hand can be "read" as guides to the future: palmistry is childish make-believe.

§ 10

THE ORGANS OF SENSE

Another section of this work tells how our wonderful sense-organs were slowly evolved, and it is enough here to observe that they

began as simple sensitive patches in the skin which, in the course of millions of years, have grown into elaborate organs. They

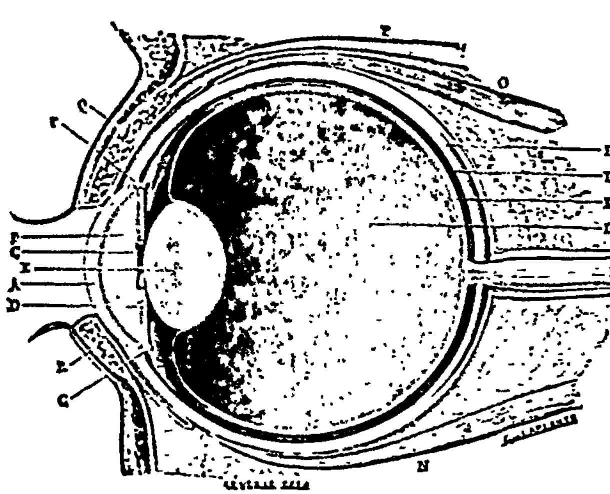
The Organs of Sense.

are the sentinels of the commonwealth of cells. For ages theirs was the vital function of locating food and announcing danger. Now, in man, they are the chief channels of those glimpses of nature which the mind unites in the marvellous structure of modern science.

The skin, to begin with, is crowded with little organs of sense. Nerves from the great centres branch out in every direction, and the fine twigs at last end in sensitive bulbs underneath the skin. The most numerous of these are for the purpose of announcing "pain." We speak of pain as something in the body-machine which we could very well spare, but a little reflection will soon tell us that it is a most benevolent institution. It announces some danger which, if it were not thus indicated by the ringing of the bell in the brain, would not be noticed, and might become fatal. Other little bulbs, especially numerous on the palm-side of the fingers, minister to the sense of touch. Others feel cold, and a different set experience heat. By careful testing, the reader can find for himself that these sensations are localised in different areas on his arm. There are other nerve-endings again for the sense of pressure.

Other sensitive bulbs, which line part of the mouth, are the receiving organs for the sense of taste. Little oval bodies stand up like a close regiment of diminutive soldiers on the upper surface of the tongue. Each of the internal cells of these "taste-buds" ends in a hair-like process, and these processes touch the nerves which convey their particular stimulation to the brain. Probably different flavours are perceived by different nerves. The tip of the tongue is richer in the little bulbs that appreciate sweet things, while the back part is richer in the means of recognising bitterness.

Substances must be in a liquid form to announce themselves to taste. For the sense of smell, on the other hand, they have to be broken up into very fine particles like a gas. Nerves from the olfactory centres in the brain branch out in the membrane which lines the upper part of the nasal cavities, and this membrane includes numerous sensory nerve-cells which act as sentinels against dangers which announce themselves in the air. An odorous body is one which gives off minute particles of its matter into the air. The sense of smell was once of the gravest importance in the animal economy, and even in men it is so highly developed that they can detect a speck of musk diluted in eight million times as much air. A very strong offensive substance like mercaptan can be "sensed" even if there is only one grain to twenty-five billion times as much air. In man, however, the sense of smell is degenerating, and many individuals have it very feebly.



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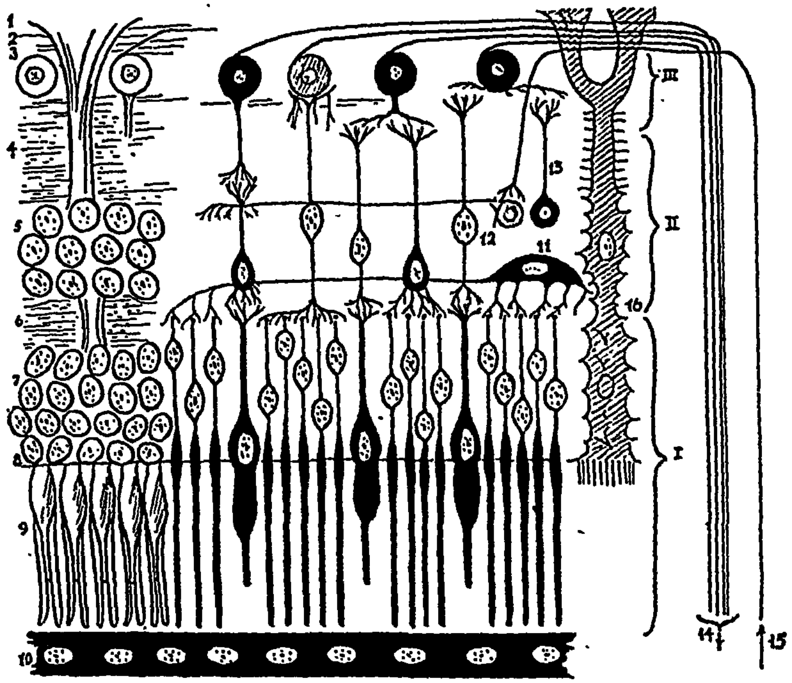
REPRESENTATION OF A VERTICAL CUT THROUGH THE EYEBALL IN ITS SOCKET.

In the figure, muscles (P, O, N) of the eyeball are shown. A is the cornea; it closes the front of the anterior chamber (B), which is filled with aqueous humour and the back wall of which is formed by the curtain of the iris (D). In the middle of the back wall is the opening of the pupil (C), through which is seen the lens (E). Behind the lens is the posterior chamber (L), filled with vitreous humour. Entering the eye from behind is the optic nerve (M), which is distributed to the retina (K). The posterior wall of the eye shows from within outwards the image-forming retina, the dark choroid with blood-vessels (I), and the firm protective sclerotic (H).

Most important of all the senses is that of vision, for nearly all the ideas of things in the mind of an ordinary person are visual images.

The Sense of Vision.

The essential part of the mechanism of this sense is the eyeball and the nerve which goes from this to the sight-centre in the brain. The eye is a camera of a most remarkable description. It is a roundish ball made of dense and



DIAGRAMMATIC CROSS-SECTION THROUGH THE RETINA OR PERCIPIENT LAYER AT THE BACK OF THE EYE. (After Hesse.)

The figure gives some idea of the intricacy of this layer, which is not thicker than the paper of this book.

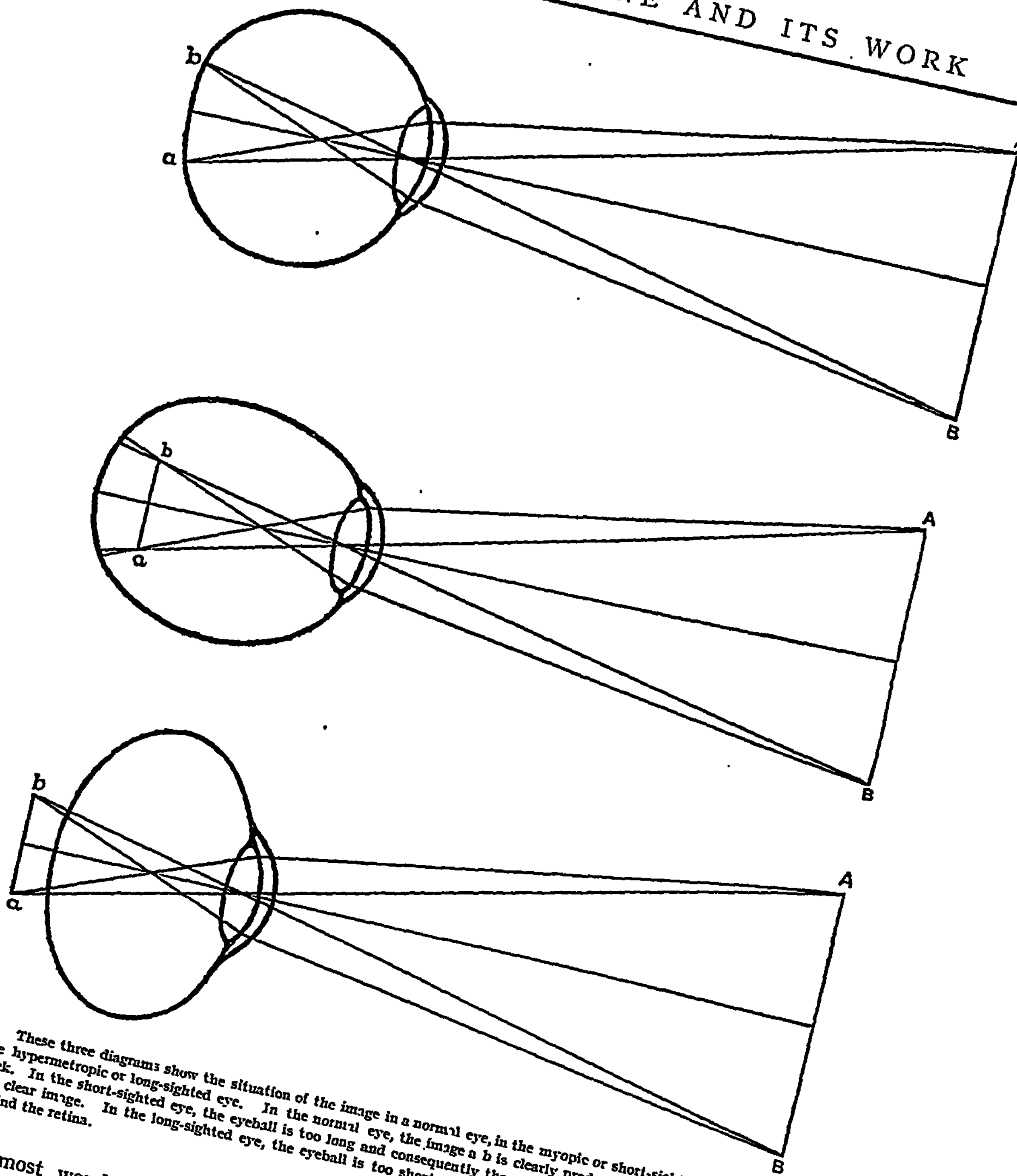
1. Inner or anterior limiting membrane, next the vitreous humour in the cavity of the eye. 2. A branch of the optic nerve dividing up. 3. A layer of ganglion cells. 4. An inner layer of nerve-fibres. 5. A layer of bipolar cells (so-called "inner granular layer"). 6. An outer layer of nerve-fibres. 7. Layer of visual cells (so-called "outer granular layer"). 8. Outer or posterior limiting membrane. 9. The rods (longer and thinner) and the cones (shorter and broader). 10. Pigment layer of the retina. 11. Tangential cells. 12. Bipolar cells. 13. An amacrine cell. 14. Centripetal fibres of the optic nerve. 15. Centrifugal fibres of the optic nerve. 16. Muller's supporting cells. I, II, III, the three areas of nerve-cells in the retina.

It is not in the least within the scope of this work to explain the minute structure of the retina; the figure has been introduced to give some impression of the complexity of the vital architecture. The essential fact is that the rods and cones somehow convert the pulses of the luminiferous ether into stimulations of the fibres of the optic nerve.

strong fibrous tissue, opaque for five-sixths of its surface, but transparent in the one-sixth which bulges out in front, as the cornea. To the interior of the cornea, separated from it by a watery fluid, there is a delicate curtain which hangs over the transparent "window" in front and forms the variously coloured iris.

This curtain is a wonderful arrangement for adapting the eye to the intensity of light which falls on it. Fibres of muscle are so ingeniously distributed in it that it can almost close the opening in a strong light, or open it wide when the light is fainter. The "iris diaphragm" with which the photographer regulates the entrance of light into his camera is merely a poor imitation of it. Moreover, it contains pigment cells, which may be crowded when the light is strong or fewer in number when the eye wants as much light as possible. So we get the black eyes (eyes rich in pigment, to mitigate the light) of the southerner, the blue eyes (with little pigment) of the dweller in the darker northern lands, and every intermediate shade and combination of them.

Behind the circular window, the pupil, is the crystalline lens, which, unlike any lens that man can make, can be altered by fine muscles so as to focus itself for any distance. Other muscles and tendons are attached to the outside of the eyeball, and they automatically turn it in the direction we want. Some men of science have found many defects in the eye, and there are defects: but when one thinks of the unconscious agencies that have built up this wonderful camera, and work it automatically every moment of our waking lives, one is not disposed to cavil.



These three diagrams show the situation of the image in a normal eye, in the myopic or short-sighted eye, and in the hypermetropic or long-sighted eye. In the normal eye, the image a b is clearly produced on the retina at the back. In the short-sighted eye, the eyeball is too long and consequently the retina—or receptive tissue—is behind the clear image. In the long-sighted eye, the eyeball is too short and consequently the clear image is beyond or behind the retina.

But the most wonderful part of it is the "sensitive plate" at the back of the eyeball. A semi-transparent membrane, which we call the retina, lines three-fourths of the interior of the eyeball (which is filled with fluid), and it is particularly developed at one spot, the real seat of distinct vision. On this "yellow spot" in each eye the rays of light form an inverted image of the object at which we are looking. The stereoscope enables us to understand how the images of the two eyes are blended, and how they enable us to see nature more perfectly.

Vision, as might be expected, is still very imperfectly understood. The retina is a very

complex layer of delicate nerve-cells, in which certain parts that are known as "rods" and "cones" seem to be the essential elements. There seems to be chemical action, though whether there are three distinct chemicals for the three primary colours, or one chemical that breaks into separate colours, or what happens, we do not know. It is generally suspected that colour-vision is connected with one or more fine chemicals which may be lacking in "colour-blind" people. However that may be, the nerve-layer closes up at the back of the eye and, as the optic nerve, conveys the images of things in some way to the conscious centre. What precisely travels along the nerve we cannot say, but to imagine that an image or picture is conveyed is to imitate children who think that words travel along a telegraph wire.

The Sense of Hearing.

The organ of hearing is not less remarkable than the eye. We have already seen that the external ear is, to use the cautious words of Professor Starling, probably of no use whatever. In cases where it has been cut off the sense of hearing was not affected at all. But it was useful and mobile in an earlier ancestor of man. From it, in any case, a narrow channel about an inch long, protected against adventurous insects by wax secreted by its glands, conducts the waves of sound to the real ear.

At the outer end of this passage the sound-waves beat upon a sensitive drum, the tympanum, a membrane of a most ingenious construction. This membrane must not have a period of vibration of its own. It must respond readily and immediately to every sort of wave that impinges on it. It is therefore so constructed that each part of it has a different period of vibration, and it is further "damped" by a little bone pressing against it on the other side. The pressure of air on the outside of the drum, which must alter with changes of pressure outside, is regulated by a channel (the Eustachian tube) running to it from the roof of the mouth.

Three little bones (the hammer, anvil, and stirrup) convey the vibrations of the drum to another drum, which is stretched across the entrance to the real ear inside the skull. As the waves of sound impinge on the tympanum and set it vibrating, the three little bones work together and repeat the vibrations on the second drum, the "oval window." Beyond this is a coiled shell which contains the real organ of hearing—a large number of hair-cells (the "organs of Corti") interlacing with the fine fibres of the auditory nerve. The vibration of the "oval window" agitates the fluid inside this organ, and the hair-cells communicate this movement to the nerves, which then convey it to the brain. Once more we have a mechanism full of ingenuity in every part, and brief descriptions of this kind are almost unjust to the various organs of our body; but to-day we should require a large volume to give an account of our knowledge of the brain and sense-organs alone. We have referred to the three small bones of the ear by which the waves of sound are conveyed to the inner ear. "The history of these bones is strange. The hammer was at an early stage of the evolution of mammals a part of the lower jaw; the anvil was the bone on the base of the skull, with which it articulated. When mastication and molar teeth were evolved in the ancestry of mammals, a new joint was formed in the lower jaw, and these two bones—the hammer and the anvil—were taken into the service of the ear."[1]

§ II

THE DISCOVERY OF HORMONES

Remarkable Discoveries about the Glands.

A physiologist would class the different parts of the body as bones, muscles, nerves, and glands, and we have in conclusion to say something about the last. We have already spoken of the myriads of tiny tubular glands which line the alimentary canal. Another mass of tubular glands make up the essential part of the kidneys. They really form a filter of a remarkable pattern. Arteries bring the blood to the kidney tubules, which are stimulated to action by the blood. Each—by vital action, not a mere physical process—takes out of the blood the fluid nitrogenous waste substances and a certain amount of water, and the tiny ducts connected with the tubules run together and carry the waste or urine to the bladder.

But the main interest to-day is in what scientific men call the "ductless" glands: glands

[1] Sir Arthur Keith, *The Human Body*.

Photo: Anderson.

STATUE SHOWING HUMAN MUSCLES.

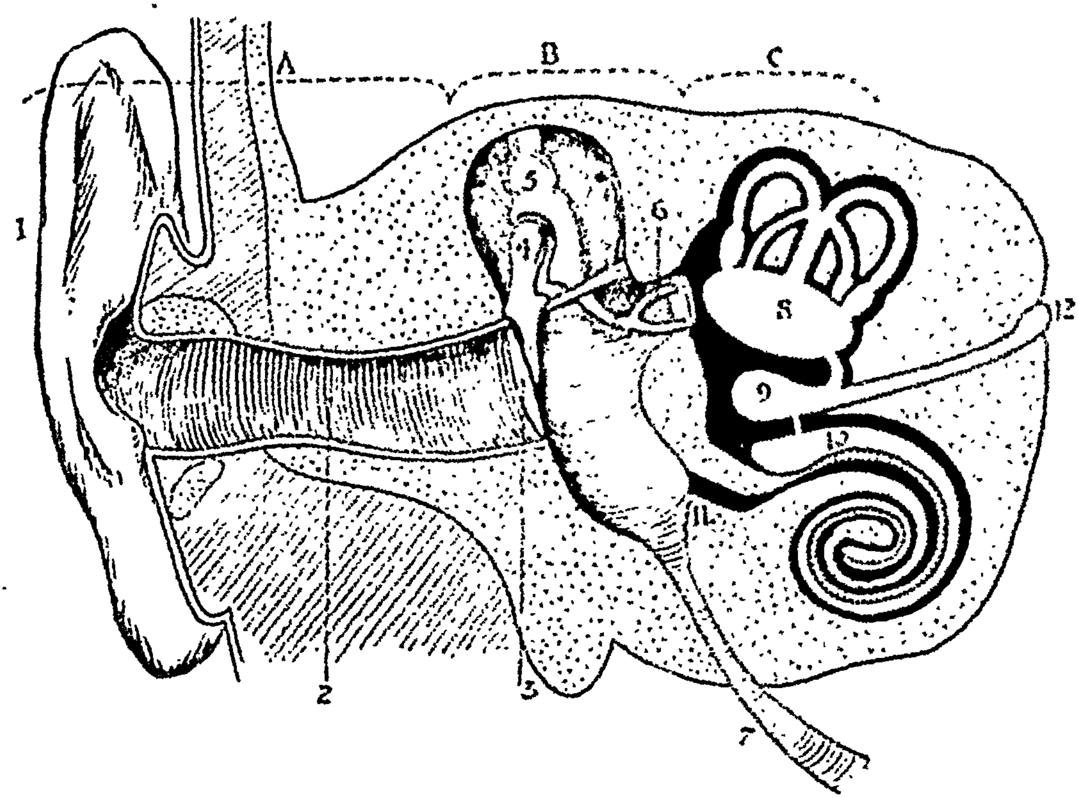


DIAGRAM OF THE HUMAN EAR (After [illegible])

A, the outer ear-passage; B, the middle ear; C, the [illegible] the inner ear.

1. The ear-trumpet or pinna, practically fixed in man and unimportant. In many mammals it helps to locate the sound. 2. The outer ear-passage with the drum or tympanum (3) stretched across its inner end. The drum vibrates when sound waves strike it. 4, 5, 6. The ear-ossicles, hammer (malleus), anvil (incus), and stirrup (stapes), which, by their movements transmit the vibrations from the drum to the inner ear. The "window" in the bony wall of the inner ear on which it abuts is called the fenestra ovalis. 7. The Eustachian tube, leading down to the back of the mouth; by it air can enter [illegible] into the middle ear. 8. The larger chamber of the inner ear, called the utriculus, with three semicircular canals arising from it. They have to do with balancing and the like. 9. The smaller chamber or sacculus connected with the coiled cochlea, the essential organ of hearing (10), containing the organ of Corti. There is also shown the endolymphatic duct (12). 11. Another "window" in the petrous bone, the fenestra rotunda. The [illegible] cavity is called the perilymph-space; it contains a fluid called perilymph; it is separated from the internal cavity of the ear by a membrane, within which there is endolymph. The dotted tissue is bone.

which extract substances from the blood but do not pour their secretion into special channels. We have already mentioned a most interesting example in the suprarenal glands: two little bodies near the kidneys, each about the size of a segment of a small orange, which pour into the blood a "chemical messenger" (or hormone) for regulating the supply of blood to the various organs.

It is one of the most remarkable discoveries of recent years, that there are numbers of little glands entirely devoted to the manufacture of hormones. "If all the glands of internal secretion were rolled together they would form a parcel small enough to go into a waistcoat pocket, yet such a small mass can influence the working and growth of the whole body." In his interesting book, which we have already mentioned, Sir Arthur Keith, referring to the dispatch of secretion to the stomach, uses the following suggestive words: The secretin, or hormone, which acts as a missive "is posted in the nearest letter-boxes or capillaries in the duodenal wall and is carried away in the general blood circulation, which serves for all kinds of postal traffic. In a postal system where there are no sorters and which must be conducted by an automatic mechanism, letters or missives cannot be addressed in the usual way. Their destination is indicated, not by their inscription, but by their shape. The molecules of secretin may be regarded as ultra-microscopic Yale

keys sent out to search for the locks of letter-boxes which they can fit and enter." They circulate round the body until they find their destination. "What is still more wonderful in this system is that the letter-boxes, or we may call them locks, have a positive attraction for the key missives which are destined for them." It was Professor Starling who named these messengers Hormones.

The thyroid glands—two little lobes on either side of the windpipe—are bodies of this nature which have attracted a good deal of popular attention of late years. The secretion formed is discharged straight into the blood stream, and for that reason they are called ductless glands or glands of internal secretion. They will be discussed at greater length in a later section of this work. Here it is enough to say that the chemical stuff, or "hormone," which they secrete increases the vitality of the tissues; it makes the tissues "greedy for oxygen," and the work goes on more briskly. Hence it is that decay or imperfect development of the thyroid glands leads to that state of bodily and mental feebleness which is called "cretinism," while the extract from the glands can be used for the purpose of "rejuvenation." This small organ, the thyroid gland, is necessary to the health and normal development of both body and mind, and this knowledge has been put to practical application in some cases with astounding results.

Near the thyroid glands are four small bodies—the "parathyroids." The function of these is not yet clear, but there is serious nervous trouble if they are removed. Then there is a "thymus gland," which seems in some way to prevent the sex-organs from developing too early. It is situated in front of the breast-bone, and must act by "postal service." The internal sex-organs themselves post a good many of these "hormones" in the blood. Everybody knows the striking difference between a normal and a castrated animal. The development of secondary sexual characteristics, such as antlers, seems to be largely stimulated by chemical messengers of this kind. One of the most interesting illustrations is in connection with the milk in the mother's breasts. How does the mammal mother come to have this rich development of her milk-glands just at the moment when it is needed? It has been discovered that, as soon as she becomes pregnant, the ovaries begin to discharge a hormone into her blood, which finds its way to the breasts and stimulates them. Probably the embryo itself also produces hormones which pass into the mother's blood, and serve a useful purpose up to the time of birth.

Finally, there is a remarkable and long neglected little body in the head, the "pituitary body," which is a rich laboratory of hormones. It controls the growth of tissues by stimulating them. When it is removed from an animal, the body becomes feeble and undersized. On the other hand, some rather unfortunate people have their pituitary body overgrown, or overactive, and they develop unpleasantly large faces, hands, and feet, or become "giants."

Such, as far as one can tell it in so brief a space, is the tale of the wonderful mechanisms in the body. Even the skin, which binds and protects this marvellous system of parts, is a remarkable organ when one has time to study it thoroughly. On the tender eyelids of a young child it is as thin as tissue paper, yet on the palms of some "horny-handed son of toil" it will produce protecting cells until it becomes an eighth of an inch thick. It is, moreover, rich in sweat-glands (which, as we saw, are most important for regulating the temperature of the body), lubricating or sebaceous glands, corpuscles for the sense of touch, and little pits in which take root the hairs which were once of great service to the body. Every internal surface also has its lining, or skin: tough where toughness is required, but so fine in the right places that gases and fluids can pass through it for breathing and nutritive purposes. "The proper study of mankind is man," said a great poet; and we may surely add that we know no more interesting study in the universe.

§ 12

Before we leave the subject of this article a further word should be said.

Mind and Body.

The comparison of the body to an engine is very useful, but it is more than a little apt to lead us astray. For the body is living, and in higher animals, at least, there is a "mind" that

counts. No one has succeeded in making clear the relation between mind and body, if there be a relation, but what we are sure of is that there are two aspects, two sides to the shield, the mental and the bodily. Just as a dome has its inner concave and its outer convex curve, inseparable from one another, two aspects of the same thing, so the living creature is a feeling, remembering, willing, and sometimes thinking being, just as really and truly as it is a feeding, moving, storing, and energy-transforming system. On the one side there is "mind," probably present even when it is not apparent to the observer; on the other side there is the routine of chemical processes which we call metabolism. Sometimes the living creature is more of a body-mind, sometimes more of a mind-body. We cannot solve the riddle: the mental or subjective and the bodily or objective activity are bound together in one. What we are quite sure of is that the ideal for the organism is a healthy body at the service of a healthy mind. Let us take an illustration of the influence of mind on body.

Reproduced by courtesy of Messrs. F. Davidson & Co.

SECTION OF HUMAN SKIN.

1. To the outside with ridges is the horny layer of the epidermis (*stratum corneum*).

2. Then comes the second layer of the epidermis, the Malpighian layer (*stratum malpighi*); and traversing this is seen the coiled duct of a sweat gland.

3. Third comes the under-skin or dermis, the seat of many glands and blood-vessels. Its surface is raised in hillocks or papillæ. Into these there run blood-vessels and nerves.

Emotions and Digestion.

The famous physiologist of Petrograd, Professor Ivan Petrovich Pavlov, was the first to demonstrate the influence of the emotions on the health of the system. Everyone knows that a good circulation and a good digestion make for cheerfulness, but the converse is also true. "A merry heart is the life of the flesh." The researches of Pavlov, Cannon, Carlson, and Crile have made it quite clear that pleasant emotions favour the secretion of the digestive juices, the rhythmic movements of the food-canal which work the nutriment downwards, and even the absorption of what has been made soluble and diffusible. On the other hand unpleasant emotions, such as envy, and mental disturbances, such as worry, hinder digestion and the smooth working of the nutritive process.

The Cult of Joy.

When the hungry man sees the well-laid table his mouth waters, but everyone knows that a memory or an anticipation will also serve to move at least the first link in the digestive chain. Professor Dearborn writes: "It is now well known that no sense-experience is too remote from the innervations of digestion to be taken into its associations, and serve as a stimulus of digestive movements and secretions." As was said of old time, "He that is of a merry heart has a continuous feast." When our joyous index is high, our digestion is good. As Dr. Saleeby has put it, freedom from care has nutritive value. It does not seem far-fetched to wonder if the joyousness of singing birds may not react on their remarkably well-developed capacities. We speak smilingly of our friend's "eupeptic" cheerfulness, but our smile is a little apt to become a materialism. We have to inquire whether our friend is not "eupeptic" because of his psychical success in the great task of happiness. The truth is that the mental and the bodily harmonies are the bass and treble of one tune.

The influence of mind on body finds a good illustration in the stimulation of the adrenal glands by strong emotion. Anger, which may be righteous, affects the production of adrenalin by the core of the adrenal glands, situated near

the kidneys. The slight increase in this powerful "chemical messenger" or hormone, which the blood sweeps away, has numerous effects through the body. It constricts the smaller

Photo: Rischgitz Collection.

LORD LISTER.

Joseph Lister (1827-1912), famous as the introducer of antiseptic methods into surgery. Following Pasteur, who showed that wounds went wrong with gangrene and the like because microbes or germs got in, Lister used a dressing, such as carbolic acid, which killed the microbes. Lister was Professor of Surgery in Glasgow, Edinburgh, and King's College, London.

blood-vessels, and there is less blood in the peripheral and more in the deeper parts. It raises the blood-pressure, excites and freshens the muscles, adds to the sugar-content of the blood, increases the coagulability of the blood and so on. In short, the whole body is prepared for a fight, and all under the influence of what was to begin with a psychical event.

"Good news, psychical if anything is, may set in motion a series of vital processes, complex beyond the ken of the wisest. What is true of digestion is true also of the circulation. Wordsworth was a better physiologist than he knew when he spoke of his heart leaping up at the sight of the rainbow and filling with pleasure at the recollection of the daffodils dancing by the lake-side. There are facts which point to the conclusion that a gladsome mind increases the efficiency of the nervous system. Good tidings will invigorate the flagging energies of a band of explorers; an unexpected visit will change a wearied homesick child, as if by magic, into a dancing gladsome elf; a religious joy enables men and women to transcend the limits of our frail humanity." [1]

Healthy-mindedness.

There is reason, then, to believe that emotion has its physical accompaniment in tensions and movements throughout the body, and in changes in the secretion of glands. There is a physiological reverberation of joy. But there must be more than this. The nervous system has a notable *integrative* or unifying function; it makes for the harmony of the bodily life. This function

[1] Thomson, *The Control of Life*, 1921.

it may discharge the better if the psychical side is finding its due development. Thus it is well known that æsthetic emotion—delight in the beautiful—is very markedly a body-and-mind reaction, affecting the whole creature as a unity. It is practically certain that many people fail in health because they starve their higher senses and minds.

We venture to go further, under the conviction that physiology and psychology must join hands—as is suggested, indeed, by the name of the new science of psychobiology. The physiological ideal is bodily health; its essential correlate is healthy-mindedness. No doubt the invalid may have a vigorously healthy mind and the athlete a mind diseased, but, on the average, the two aspects of health must develop together. Hence the importance of mental dieting, mental gymnastics, mental rest, mental play, mental stores; though these must be sought as ends in themselves, not as aids to digestion!

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XI

HOW DARWINISM STANDS TO-DAY

VARIATION—SELECTION—HEREDITY—MENDELISM

WHEN people speak of Darwinism they sometimes mean the general idea of evolution—that the present is the child of the past and the parent of the future. Now the evolutionary way of looking at things has certainly been confirmed by the progress of science and is almost unanimously accepted by competent judges to-day. This horse that gallops past on the tiptoe of one digit on each foot is the natural outcome of an ancestral stock of small-hoofed mammals that used to plod about in the Eocene meadows, with four toes on each fore-foot and three and a vestige on each hind-foot. This bird that flies past is the descendant of such an old-fashioned type as the Jurassic Archæopteryx—an archaic bird with teeth in both jaws, a long tail like a lizard's, and a sort of half-made wing. And this first-known bird must be traced back to an ancestry among the extinct Dinosaur reptiles, though the precise pedigree remains hidden in the rocks. These reptiles must be traced back to certain primitive amphibians, and these to certain old-fashioned fishes, and so on, back and back, till we lose our clue in the thick mist of life's beginnings. If this is Darwinism it stands more firmly than ever, except that we are more keenly aware than in Darwin's day of our ignorance as to the origin and affiliation of the great classes. But, frankly, the only scientific way of looking at the present-day fauna and flora is to regard them as the outcome of a natural evolution. In a previous chapter this statement has been justified.

Universal Acceptance of the Evolution Idea.

Photo: Becker and Maas.

PROFESSOR WILLIAM BATESON, F.R.S.

One of the most distinguished of the experimental evolutionists, he has made fundamental contributions to our knowledge of Mendelian heredity and of variation. He has confirmed Mendel's theory and added important elaborations. He has shown that discontinuous variation or mutation is of frequent occurrence. He was President of the British Association on its visit to Australia in 1914.

The Factors in Evolution.

But "Darwinism" is more properly used, in a stricter sense, to mean Darwin's theory of the factors in evolution. If birds sprang from Dinosaur reptiles, if the modern horse is the descendant of Eohippus, which was about the size of a fox-terrier, how did the gradual transformation come about? There were many evolutionists before Darwin, and some of them propounded theories as to the factors in the age-long process. But Charles Darwin and his magnanimous fellow-worker, Alfred Russel Wallace, thought out a co-

A RAT-BREEDER'S TRIUMPH.

A "Dutch-marked" cross between a black and a white rat, bred by Mr. H. C. Brooke. It shows a probably unique symmetry of markings. The black and white rats of the fancier are both derived from the common brown rat (*Rattus norvegicus*) and have nothing to do with the wild black rat (*Rattus rattus*).

evolution any hesitation as to the *fact*. Our frankness in admitting difficulties and relative ignorance in regard to the variations and selections that led from certain Dinosaurs to Birds cannot be used by any fair-minded inquirer as an argument against the idea of evolution. For how else could Birds have arisen? As Wallace said in 1888, "Descent with modification is now universally accepted as the order of nature in the organic world." But the question before us is this: What, as regards the factors in evolution, have been the changes since Darwin's day?

§ 1

The Three Problems of Evolution.

There are three great problems before the evolutionist: (1) What is the origin of the new? (2) What are the laws of inheritance? (3) What are the sifting methods that operate on the raw materials provided and determine survival? In other words: what are the originative factors, what are the laws of entail, and what are the directive or sifting factors?

Evolution depends on new departures, peculiarities, idiosyncrasies, divergences, freaks, sports, a little more of this, a little less of that—in short, organic or constitutional changes. These are technically called variations and mutations. In other words, evolution—whether progressive or retrogressive—depends on the emergence of novelties. When there are no novelties there can be no evolution. The Lamp-shell, Lingula, seems to have remained stagnant for many millions of years—a fine creature, but icily perfect.

Heredity is the relation of organic continuity between successive generations, the living on of the past in the present, the flesh and blood linkage between an individual and his forbears on the one hand, his offspring on the other. The individual is like a lens into which rays from parentage and ancestry converge, from which they diverge again to the progeny.

Heredity is the reproductive relation which

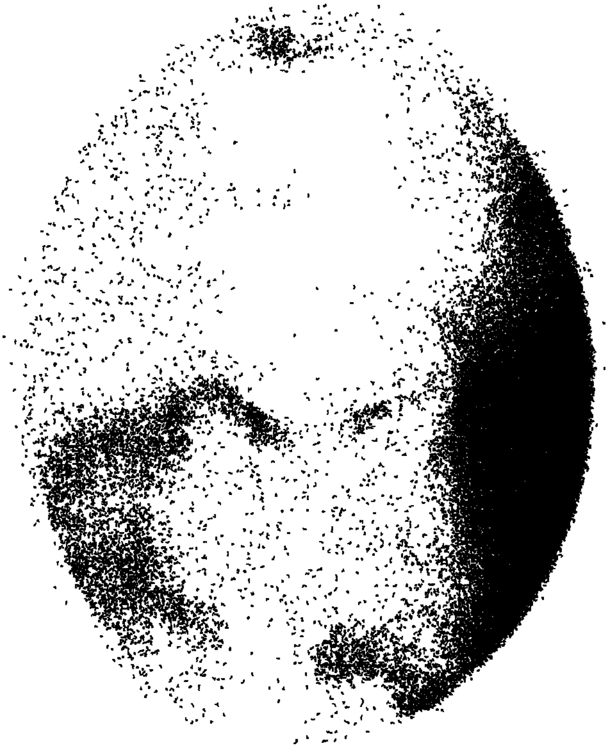
pure-bred tall pea and a pure-bred dwarf pea are crossed the offspring are all *tall*.

Now one of the great changes that has come about since Darwin's day is a recognition of the frequency of discontinuous variations, by which we mean sudden novelties which are not connected with the type of the species by intermediate gradations. We may think of the white crow or the weeping willow. The Proteus leaps as well as creeps. Especially through the investigations of Professor William Bateson and Professor Hugo de Vries, it has become plain that changes of considerable magnitude may occur at a bound. When the new character that suddenly appears, such as a Shirley Poppy or a short-legged Ancon Sheep, has a considerable degree of perfection from its first appearance, is independently heritable to the offspring, and does not blend or average off, it is called a *Mutation*. Professor de Vries writes: "The current belief assumes that species are slowly changed into new types. In contradiction to this conception the theory of mutation assumes that new species and varieties are produced from existing forms by sudden leaps. The parent type itself remains unchanged throughout the process, and may repeatedly give birth to new forms. These may arise simultaneously and in groups, or separately at more or less widely distant periods." This was strikingly illustrated by the sporting Evening Primrose (*Œnothera lamarckiana*), a species of North American origin, which de Vries found at Hilversum in Holland, and which proved to be in a very changeful mood. Almost all its organs were varying, as if swayed by a restless internal tide. It gave rise abruptly to numerous new forms which bred true. It illustrated species in the making.

Darwin found the raw material of evolution in small fluctuating variations, which are no doubt of frequent occurrence. Since Darwin's day it has become not only possible but necessary to attach much importance to discontinuous mutations. The contrast was aptly illustrated by Sir Francis Galton, who compared the varying organism to a polyhedron (a solid body with many faces) which can roll from one face to another. When it settles down on any particular face it is in stable equilibrium. Small disturbances may make the polyhedron oscillate, but it always returns to the same face.

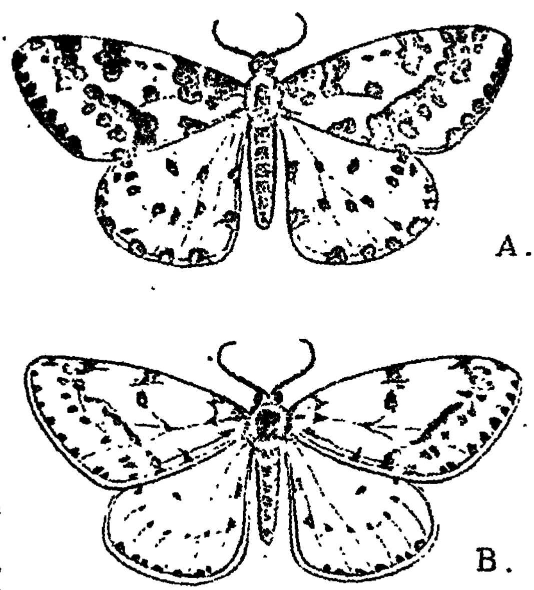
JAPANESE LONG-TAILED FOWL OR TOSA FOWL.

In this extraordinary breed, which is believed to be of very ancient origin, the feathers of the tail show continuous growth, reaching 7 to 8 feet, and in extreme cases 18 feet. This seems to be a physiological mutation. The offspring of a cross between a Tosa cock and a white cochin Bantam hen yielded males with the Tosa coloration except that every feather was barred with white. The males had abnormally long middle tail-feathers, but not so long as in the Tosa cock. The female offspring were like Tosa hens.



Darwinian would point to the fact that constitutional or germinal variations in eyes are common. Variants with weak eyes and with a bias in that direction would naturally seek out caves. The giraffe has got a very long straight neck because of the cumulative result of generation after generation of stretching up to the branches of the acacia-trees. With certain provisos Darwin inclined to accept this view as supplementary to his own. But the modern Darwinian would point to the fact that constitutional or germinal variations in the proportions of different parts of the body are common. Giraffe variants in the direction of a long neck would prosper, and would become the leaders of the race. Long noses often run in families, but the length of the nose is not due to the vigour with which generations have used the handkerchief.

No one doubts the reality of modifications: one has only to look at the tanned skin of the African explorer. But what is doubtful is that a modification can be passed on from the individual that acquires it to his offspring—passed on as such or in any representative degree. The modification may be very important, even life-saving, for the individual, but unless it can be transmitted it is not in any direct way important for the race. The scepticism as to transmission of bodily modifications was focussed by Sir Francis Galton and by Professor August Weismann; and many would say that one of the great changes in Darwinism since Darwin's day has been the abandonment of belief in the Lamarckian postulate of the transmission of modifications. There are some difficult cases, however, which suggest that biologists must not be in a hurry to shut out the possibility of such transmission. Admitting a few difficult cases, we can only record our impression that the available evidence indicating a transmission of "acquired characters" as such or in any representative degree is very inconclusive. But this would not be admitted by such a distinguished zoologist as Professor E. W. MacBride; and the scientific outlook should be that of an open mind, associated with an eager search for more facts.



VARIATION IN THE MAGPIE MOTH.

This common moth, *Abraxas grossulariata*, which ranges from Britain to Japan, and is famous for its extraordinary number of variations in colour and markings. Such slight differences as those between the type A and the variety B (*lacticolor*) illustrate the minute variations which form part of the raw material of evolution.

Those who are unfamiliar with the subject often ask how a race could make progress at all if acquired characters were not transmitted from generation to generation. The answer is that the changes which make for racial progress are variations and mutations—*arising from within*, from disturbances and rearrangements, permutations and combinations, in the germ-cells from which new individuals arise. In 1796 the utmost speed of the trotting horse was stated at a mile in 2 min. 37 sec.; in 1896 at 2 min. 10 sec. Does it not follow that the trotting horse has been improved by the transmission of the results of the systematic training in trotting? It is certain that this conclusion does not follow from the available evidence, which points to the conclusion that the improvement in speed has been mainly due to the selective breeding of constitutionally swift horses. The trotter is born, not made.

It should also be understood that modifications may reappear, *not because* they have been transmitted, but because the conditions which originally brought about the change may still persist and produce the same effect on the offspring. And as to the inheritance of disease, this is apparently

confined to constitutional diseases which are due to disturbances in the germ-cells. Diseases due to peculiarities of occupation or diet are not transmitted as such, though an unborn offspring may be poisoned before birth, or even infected with some disease microbe.

Another common misunderstanding must be cleared up, namely, the idea that if peculiarities directly induced by improvements in human "nurture" (surroundings, food, and habits) are not handed on to the offspring, then such improvements are not of great importance. But if the beneficial results of improved function and environment are not as such transmitted, it becomes all the more urgent that they should be reimpressed on each successive generation. If they are not entailed, then it is all the more important that they should be *re-acquired*. Moreover, these ameliorations of "nurture" (in the wide sense) may serve as the liberating stimuli that encourage the unfolding of new variations of a useful sort. Besides, it has to be borne in mind that, although the direct effects of fresh air, exercise, good food, beautiful surroundings, pleasant work, and the like, may not be transmitted as such or in any representative degree, they may increase the general vigour of the next generation, and will certainly do so when the mother influences the offspring before birth—an influence which is not in the strict sense part of the inheritance. Given a constitutional taint or weakness, it may be counteracted by suitable "nurture," but that will not make it disappear from the inheritance. It will crop up in a later generation if it gets a chance. In breeding animals and cultivating plants there seems to be no use working with individuals showing advantageous *modifications*; the only hope is to select from among advantageous *variations* or *mutations*. Finally, it should be noted that if advantageous modifications are not entailed, which may be a matter for regret, the same non-transmission will hold in regard to disadvantageous modifications, whereat we may congratulate ourselves.

§ 4

Darwin had no theory of the origin of variations, and we must join with him in saying "our ignorance of the laws of variation is profound." This is the central problem of evolution—the origin of the new. Yet certain possibilities have become clearer since Darwin's day. When a white blackbird is hatched, when an albino child is born, when a calf appears without horns or a kitten without a tail, we interpret these variations as due to the dropping out of the relevant hereditary item in the inheritance, and we know that in the history of the germ-cells there are definite opportunities for such losses.

Origin of Variations.

When, on the other hand, an offspring has more than usual of a certain character we can interpret this as due to its getting a double dose—from both sides of the house—of the hereditary item in question. If both parents are very dark and come of very dark stocks, the offspring may be darker still, and the same holds terribly true of a double dose of some disadvantageous character, such as deaf-mutism. The individual life always begins in the fertilised egg-cell, and there may be accentuation of a character, we say, if it is strongly represented both in the paternal and in the maternal hereditary contributions: In the sperm-cell as in the egg-cell there is a complete set of hereditary "factors" or initiatives, and these two sets come into intimate and orderly union in fertilisation. When the fertilised egg develops into an embryo and into a young creature, there may be an expression of some paternal peculiarities and some maternal peculiarities, with a new pattern as the result. It must be understood that although there is a complete assortment of hereditary qualities in the egg-cell and also in the sperm-cell, it is usually only one set that finds expression in the offspring in regard to any particular structure. The child may have its mother's hair, its father's chin. In some cases a father's character as regards some particular feature is seen only in his sons, not in his daughters. But the feature may appear in his daughter's sons.

When the human variant shows a new pattern of a particularly happy kind, we call it "genius"; when the outcome is more dubious we say "crank". And the animal kingdom is full of geniuses and cranks. Our point, however, is just this, that fertilisation offers an opportunity for new permutations and combinations. If we may compare an inheritance to a pack of cards, each hereditary constituent or "factor"

Reproduced by courtesy of Messrs. Methuen & Co. from "A History of Birds" by W. P. Pycraft. (After a drawing by G. E. Lodge.)

A FACTOR IN THE STRUGGLE FOR EXISTENCE (PEREGRINE FALCON ATTACKING A ROOK)

The Peregrine Falcon, which has been described as "the most powerful bird for its bulk that flies," preys largely on other birds, which it attacks during flight. The Falcon's aim is always to get higher than its quarry; it then "stoops" from above, killing not by force of impact but by the grip of its strong talons. As in many birds of prey, the female is larger and stronger than her mate and can hunt larger game.

corresponding to a card, then there is in fertilisation a re-shuffling, just as there is in the maturation of the germ-cells an opportunity for cards being lost. We may say, then, that an increased knowledge of the history of the germ-cells since Darwin's day has made it possible to understand how certain kinds of variations may arise.

If we probe a little deeper, we see the possibility that the stimuli of outside changes, e.g. of climate, may saturate through the organism *and provoke the complex germ-cells to change.* Thus Professor W. L. Tower subjected potato-beetles at a certain stage of their development to very unusual conditions of temperature and humidity. The beetles themselves were not changed, for these hard-shelled creatures do not lend themselves to external modification. But in a number of cases the *offspring* of the beetles showed remarkable changes, e.g. in colour and markings. And the offspring of these variants did not revert to the grandparental type. In such a case it looks as if an environmental stimulus penetrating through the body serves as the liberator or stimulus of variability in the germ-cells.

It may seem for a moment that this case of the potato-beetles indicates the inheritance of the results of environmental influence. But it must be carefully noticed that the parent beetles showed no modification or acquired character. What happened was that a peculiarity of environment saturated through the body, and started a germinal peculiarity, which all biologists are agreed in regarding as heritable. Similarly, persistent alcoholism on the part of a strong parent may prejudice the offspring by provoking disturbance in the germ-cells. But this is very different from the transmission of hardened liver or any other specific modification. Everyone knows that alcoholism of parents does not make for vigorous progeny, but it must be insisted that this does not bear very directly on the technical problem of the transmission of modification. In most cases what is inherited in the alcoholic lineage (rarely a long one) is a constitutional defect, e.g. lack of control. In some cases the parental intemperance affects the germ-cells prejudicially; though in some animals the results of experiments do not corroborate this. It seems to vary with the organism. Finally, the offspring of an alcoholic mother may be badly handicapped before birth, but this has as little bearing on the transmission of acquired characters as the fact that whisky babies do not thrive. It is not legitimate to re-define "acquired characters"; the term means—modifications of structure acquired in the individual lifetime as the direct result of peculiarities in surroundings, food, and function.

Professor Weismann laid emphasis on the somewhat subtle idea that the complex germ-plasm, which somehow contains the whole inheritance, might be prompted to vary by fluctuations in the nutritive stream of the body. Just as poisons in the blood may deteriorate the germ-cells in definite ways, so the gentler influence of slight changes in nutrition may induce the germ-cell to internal re-arrangements which are by and by expressed as profitable variations. It should not be forgotten that differences in diet determine whether the grub of a bee is to develop into a worker or into a queen.

It seems fair to say that the problem of the origin of variations is not so dark as it was in Darwin's time. At the same time no one can pretend to understand the emergence of the distinctively new. The germ-cell is a living creature in a single-cell phase of being, and it may be that its variations are the outcomes of a primary quality of living creatures, inherent in the germ-cell—the capacity of making experiments in self-expression.

§ 5

As regards Heredity.

Darwin was one of the first to show that the mysterious problems of heredity could be attacked scientifically, and his cousin Sir Francis Galton went much further. But it is unfortunate that neither of them knew anything about the Abbé Mendel, who published papers in 1865 which have revolutionised the whole subject. His work remained practically unknown till 1900.

Mendelism.

There are three fundamental ideas in Mendelism. The *first* is the idea of "unit-characters," and this requires a little patience. By an inheritance is meant what the living creature is or has to start with, when it is represented by a fertilised egg-cell. Now it has been discovered that an inheritance is, in part, built up of numerous, more or less clear-cut, crisply

defined, non-blending characters, which are continued in some of the descendants as definite wholes, neither merging nor dividing. We may think of the colour of the eye, the quality of the hair, the shape of the nose. Strictly speaking, what lies in the inheritance is not the character as seen in the adult but a germinal representative (technically called a "factor" or "gene") of the character. The full-grown character, say the shape of the nose, is, as it were, *a product of the germinal representative and the surrounding influences which operate during development.* It is also necessary to understand that an adult character, like the quality of the hair, may be represented in the germ-cell by several factors. Moreover, one germinal factor, e.g. the initiative for developing dark pigment, may influence several characters in the adult.

If a man has his fingers all thumbs, i.e. with two joints instead of three, this peculiarity (called "brachydactylism") is sure to be continued in a certain proportion of his descendants; and we call it a "unit-character." The persistence of the Hapsburg lip in the Royal Houses of Austria and Spain is a good instance of how a unit-character comes to stay for many generations. Night-blindness, or the inability to see in dim light, has been traced through a lineage since near the beginning of the seventeenth century—another illustration of the persistence of a unit-character. We do not precisely know what the germinal factors of the unit-characters are like, but in some cases it is known that they lie in linear order in the nuclear rods or chromosomes. In some instances (though it is impossible in a few words to explain *how*) we know what region of the chromosome the factor occupies. But the most important point is that the unit-characters (or their factors) behave as if they were definite entities, like the radicals in chemistry, which can be shuffled about and distributed to the offspring in some degree independently of one another. Thus in the lineage of the "night-blind" it was not every individual that showed the peculiarity, but only a certain proportion in each generation.

COMBS OF FOWLS.

A. Single serrated comb, as in Leghorns and Minorcas.

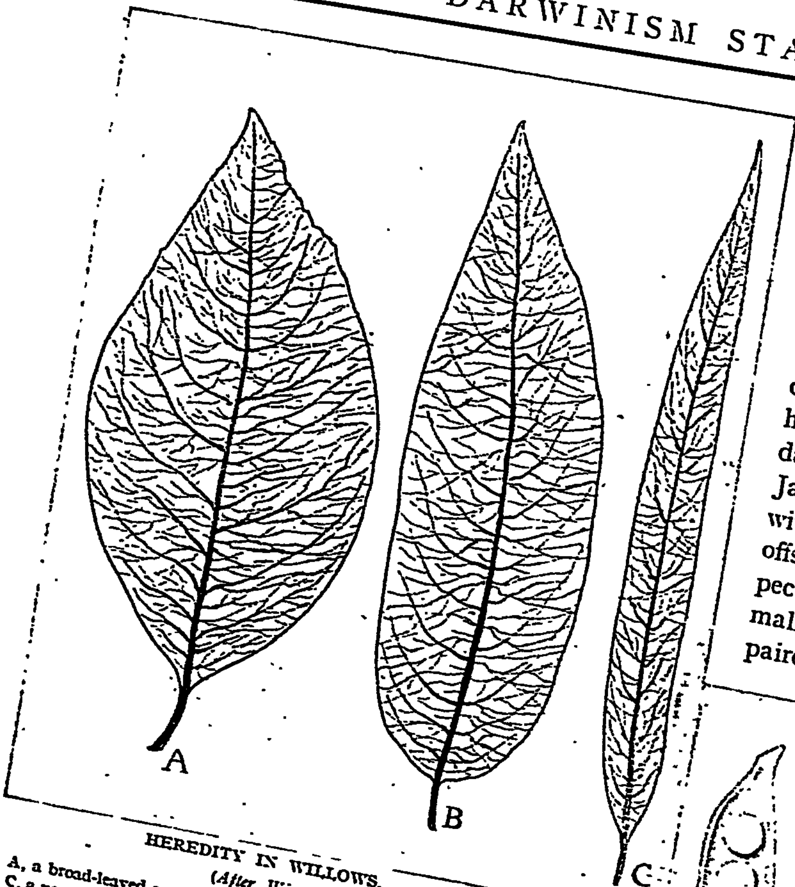
B. Pea comb, with three well-marked ridges of little papillæ, the median one a little higher than the others, as in Indian game-fowls and Brahmas.

C. Rose comb, with a flattened area bearing papillæ, and behind these a pike, as in Hamburgs and Rose-combed Dorkings.

The pea character shows definite dominance, thus pea × single yields pea. The rose character also shows definite dominance, thus rose × single yields rose.

But rose × pea yields out of sixteen cases an average of nine "walnuts," a different kind of comb altogether. The walnut comb has no distinct papillæ like the rose, or ridges like the pea. It shows a corrugated surface suggesting a walnut, and there is generally a curious band of bristles crossing the comb at the beginning of the posterior third. The rest of the members of an average sixteen series from rose × pea are three "rose," three "pea," and one single—a result which admits of reasonable Mendelian interpretation.

In his masterly book on *Mendelism* Professor R.C. Punnett refers to a unit-character as fol-



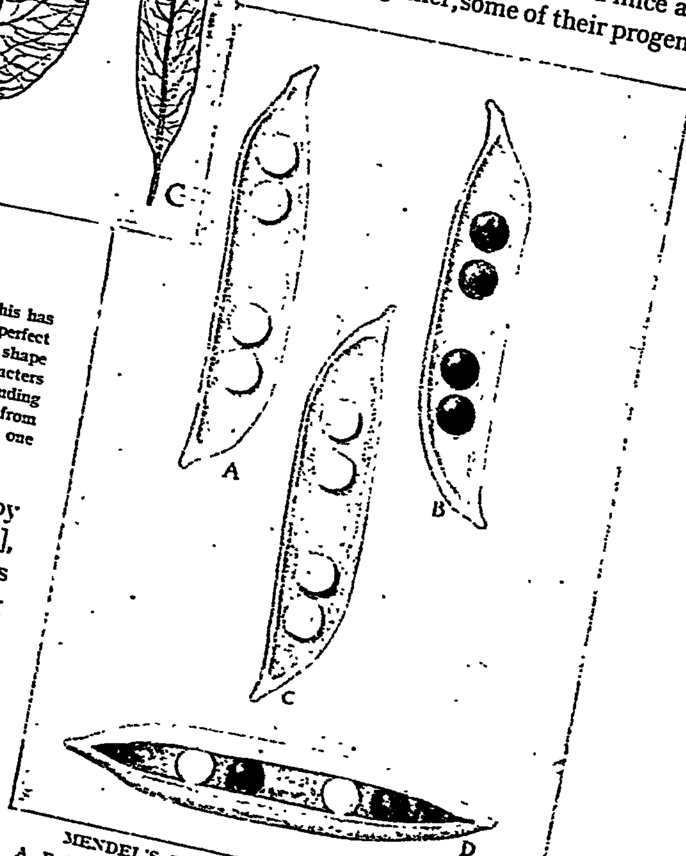
HEREDITY IN WILLOWS.
(*After Wiesner.*)
A, a broad-leaved variety, the one parent.
C, a narrow-leaved variety, the other parent.
B, the hybrid offspring, intermediate between the two. This has an appearance of *blending*, but it may be a case of imperfect dominance, as in the Andalusian fowls. Or it may be that the shape of the leaf depends upon a number of Mendelian unit characters which are not linked together but produce an appearance of blending by their fortuitous distribution in the offspring. If some come from the one parent and some from the other they may neutralise one another, with an *apparent* "blend" as the result.

lows: "Unit-characters are represented by definite factors in the gamete [or germ-cell], which, in the process of heredity, behave as indivisible entities, and are distributed according to a definite scheme. The factor for this or that unit-character is either present in the gamete or it is not present. It must be there in its entirety or be completely absent."

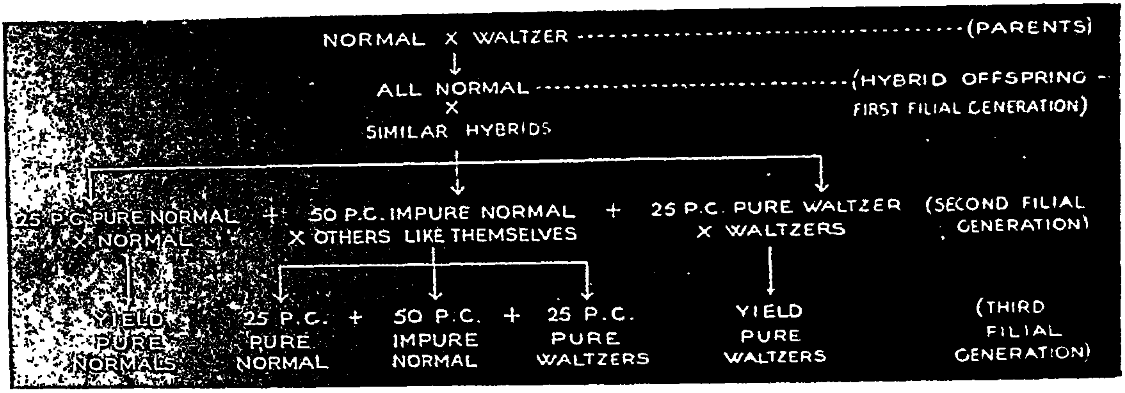
§ 6

The *second* fundamental idea in Mendelism is that of *dominance*. When Mendel crossed a pure-bred tall pea with a pure-bred dwarf pea the offspring were all tall. So he called the quality of tallness dominant to the recessive quality of dwarfness, which the hybrid offspring kept, as it were, up their sleeve. The dwarfness is not expressed in the hybrid peas, but it must be part of the inheritance, for it reappears in a quarter of the progeny of the hybrids if these are inbred or allowed to self-fertilise.

The Japanese have reared a race of peculiar waltzing mice, which have many strange habits, e.g. of dancing round and round. If a Japanese waltzing mouse is crossed with a normal mouse, all the hybrid offspring are normal, the waltzing peculiarity being recessive to normality. But if these hybrid mice are paired together, some of their progeny



MENDEL'S LAW ILLUSTRATED IN PEAS.
A. Pod of a yellow-seeded pea, the one parent (dominant as to seed-colour).
B. Pod of a green-seeded pea, the other parent (recessive as to seed-colour).
C. Pod of the hybrid offspring (the first filial generation), with only yellow seeds. Yellow-seededness is dominant and green-seededness recessive.
D. The next generation (the second filial generation) shows the occurrence of both yellow seeds (left light) and green seeds (shaded dark).



are waltzers—in the proportion of one waltzer to three normals, which is called the Mendelian ratio. If one of the waltzers of the second generation pairs with another waltzer, the progeny are all waltzers, which shows that the factor for normal locomotion has disappeared from the inheritance along this line. It is a curious fact that one of these second generation waltzers might be conscientiously sold in the market as a pure waltzer, although its parents were normal and one of its grandparents likewise. To return to the beginning, if a waltzing mouse is crossed with a normal mouse, all the offspring will be normal. Normality is dominant; waltzing is recessive. If these normal hybrids pair, their offspring will be 25 per cent. pure waltzers and 75 per cent. apparently normal mice. But of the 75 per cent. apparently normal a third will be pure normals, yielding nothing but normals when bred with others like themselves. But the other two-thirds, though apparently normal, have, like their immediate parents, the waltzing character up their sleeve, for when they are paired together they yield 25 per cent. pure normals, 50 per cent. apparent normals, and 25 per cent. pure waltzers. It is impossible to keep this clearly in mind without some schematic formulation, such as the above.

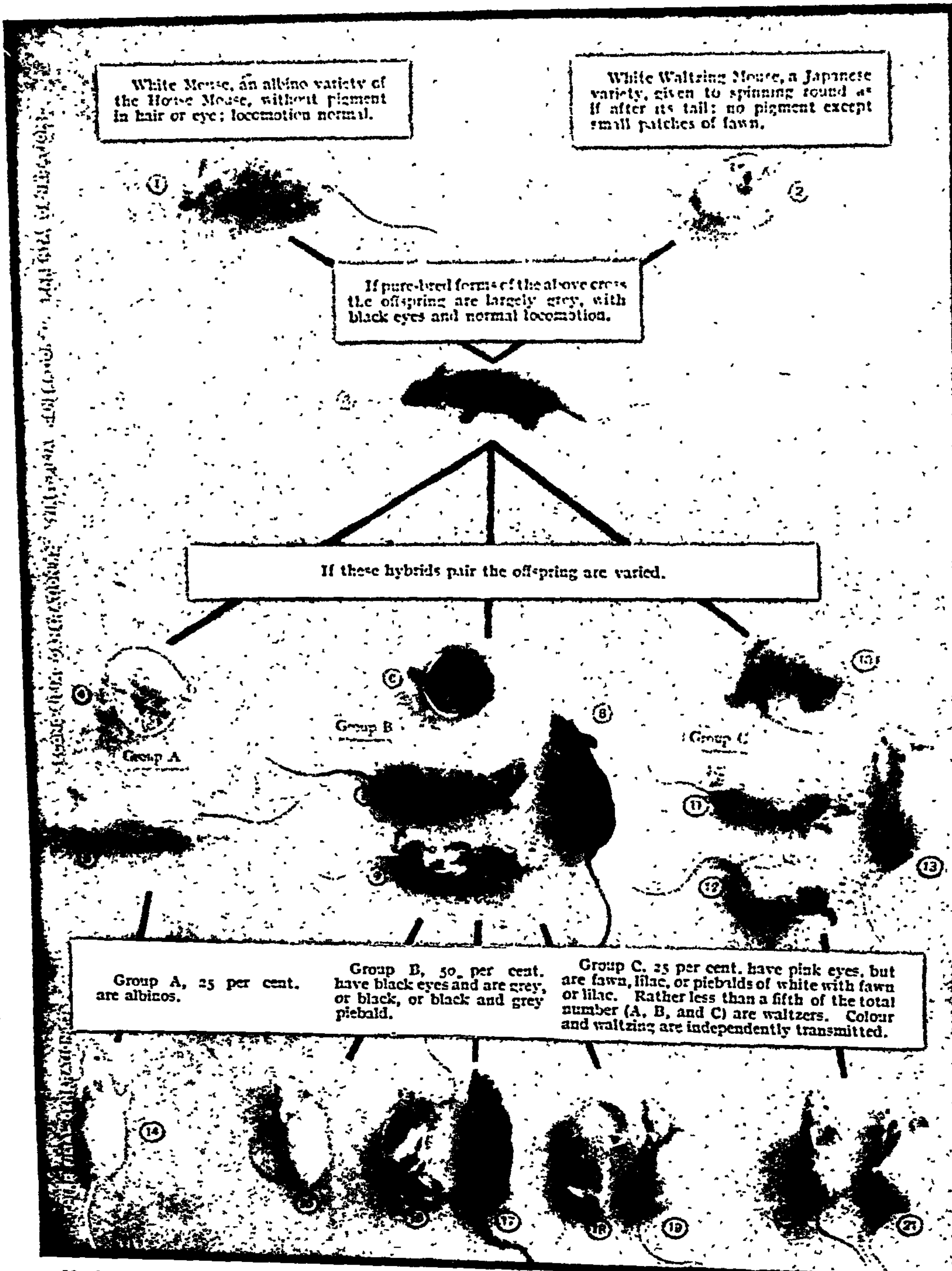
In the case of the mice the character of normal locomotion is dominant over the recessive character of waltzing, but it must not be supposed that the dominant character is necessarily the one nearest the normal type. Thus a short tail in cats is dominant (somewhat imperfectly) to the ordinary tail; the appearance of extra toes in poultry is dominant to the presence of the normal four toes; hornlessness in cattle is dominant to the presence of horns.

Among the many characters which are now known to exhibit Mendelian inheritance, the following may be cited, the dominant condition being named first in each case: Normal hair and long Angora hair in rabbits and guinea-pigs; kinky hair and straight hair in man; crest and no crest in poultry; bandless shell in the wood-snail and banded shell; yellow cotyledons in peas and green ones; round seeds in peas and wrinkled forms; absence of awn in wheat and its presence; susceptibility to "rust" in wheat and immunity to this disease; two-rowed ears of barley and six-rowed ears; markedly toothed margin in nettle leaves and a slightly toothed margin. Why one character should be dominant and another recessive is not known: a positive feature, like a banded shell in the snail, may be recessive; and a negative feature, like hornlessness in cattle, may be dominant.

It should be noted that in many cases of Mendelian inheritance the dominance in the offspring is not complete; thus, if black Andalusian fowls be crossed with white ones the progeny are "blue" Andalusians—a sort of diluted black. These "blue" Andalusians do not breed true; when paired together they yield 50 per cent. "blues," 25 per cent. blacks, and 25 per cent. peculiar whites splashed with grey.

§ 7

The *third* fundamental idea in Mendelism is perhaps more difficult to grasp than the others. Mendel supposed that the hybrid between the tall pea and the dwarf pea produced two kinds of germ-cells in approximately equal numbers—one contingent carrying the factor for tallness and the other contingent carrying the factor for



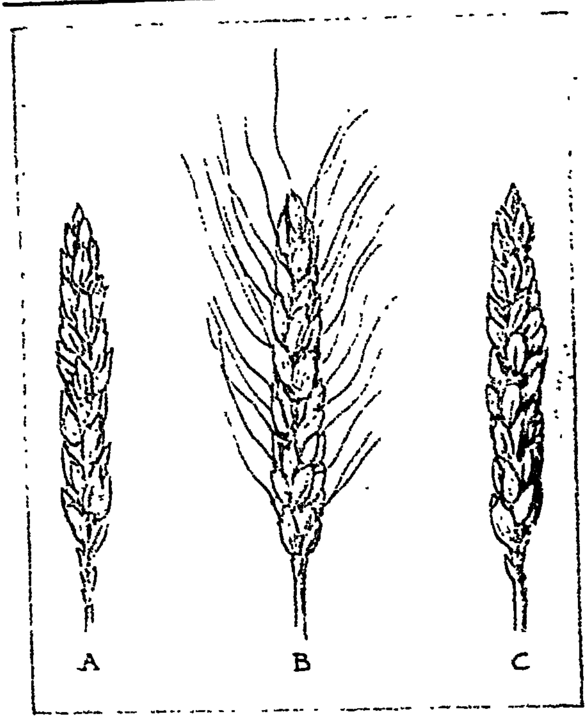
Members of Group A mated together produce only albinos like themselves.

Members of Group B mated together produce greys only like (3), or a mixed litter of albinos, greys, fawns, and piebalds of these.

Members of Group C mated together produce fawns, lilacs, piebalds of these, and an occasional albino.

Photo: British Museum (Natural History).

MENDELISM IN MICE.



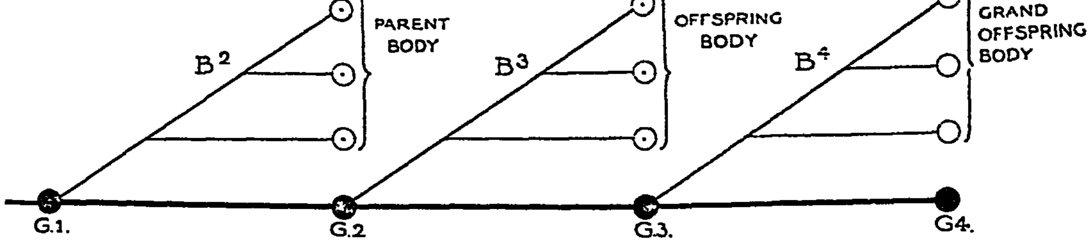
MENDELIAN INHERITANCE IN WHEAT.
(*After R. H. Biffen.*)
A. Stand-up wheat, with no beard, the one parent.
B. Bearded wheat, the other parent.
C. The hybrid offspring, with no beard.
This shows that the beardless condition is dominant and the bearded condition recessive.

dwarfness. In other words, each germ-cell is "pure" with respect to the factor of any particular unit-character. Suppose a long-haired rabbit crossed by a short-haired rabbit, the offspring will be all short-haired. But out of eight ova produced by a female hybrid offspring, four will have the factor for long hair and four the factor for short hair. Similarly, out of eight sperm-cells produced by a male hybrid offspring, four will have the factor for long hair and four the factor for short hair. Suppose these hybrids interbreed, and the fertilisation of the ova by the spermatozoa is fortuitous, then two egg-cells with the short-hair factor will be fertilised by two sperm-cells with the short-hair factor, yielding two quite pure short-haired offspring; two egg-cells with the long-hair factor will be fertilised by two sperm-cells with the long-hair factor, yielding two quite pure long-haired offspring: two egg-cells with the short-hair factor will be fertilised by two sperm-cells with the long-hair factor, yielding two impure short-haired offspring like the hybrid parents; and, finally, two egg-cells with the long-hair factor will be fertilised by two sperm-cells with the short-hair factor, yielding other two impure short-haired offspring like the hybrid parents. So the result must be two pure short-haired offspring, plus four impure short-haired offspring, plus two pure long-haired offspring. If the impure short-haired rabbits are interbred, their offspring (the third filial generation) will show the same ratio, 1 : 2 : 1, more and more exactly the larger the numbers dealt with.

§ 8

Germinal Continuity.

One of the great post-Darwinian advances is the recognition of the fact of germinal continuity—made clear by Galton and Weismann. While most of the material of the fertilised ovum is used to build up the body of the offspring, undergoing in a very puzzling way differentiation into nerve and muscle, blood and bone, a residue is kept



THE IDEA OF GERMINAL CONTINUITY.

G1. A fertilised ovum developing into a lineage of body-cells (B^2) and a lineage of germ-cells (the dark thick base-line). G2. Germ-cell which starts the offspring of the next generation, with its body-cells (B^3) and its germ-cells along the base-line. G3. A germ-cell starting the grand-offspring, with its body-cells (B^4), e.g. ectoderm, mesoderm, and endoderm, and likewise its germ-cells along the basal "germ-track," G3 to G4.

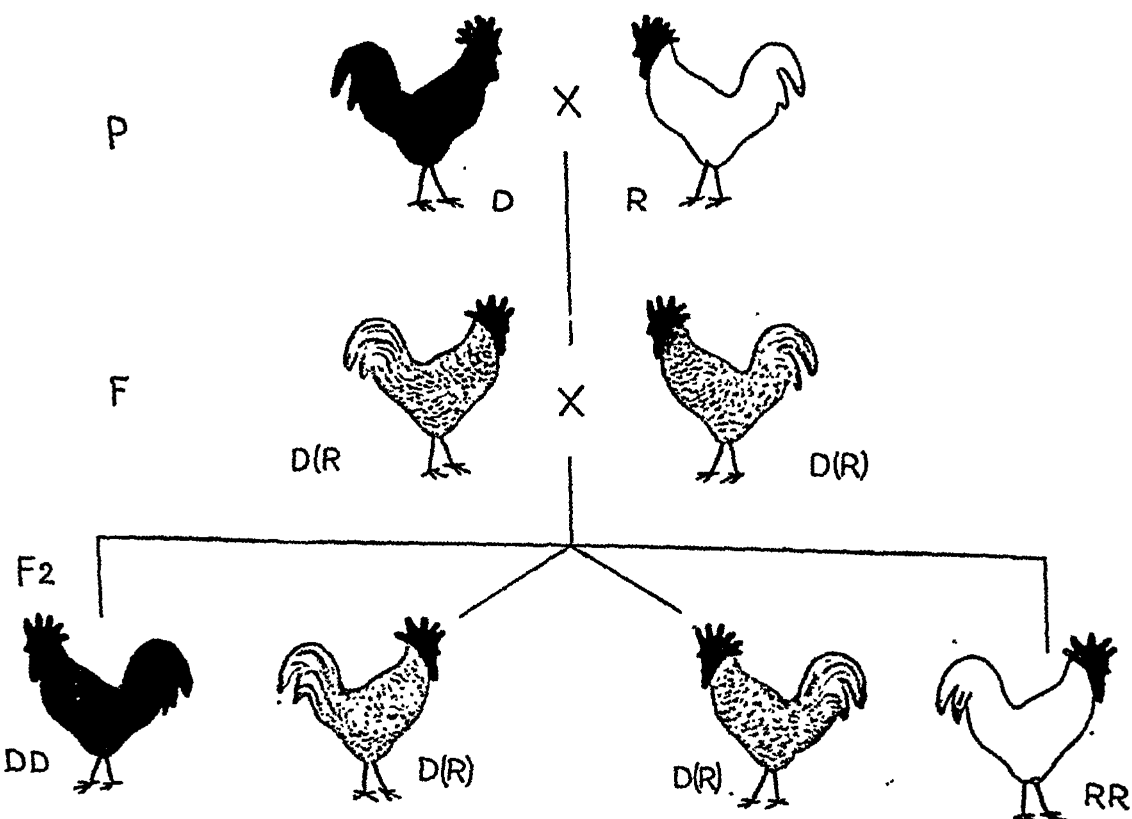
The base-line represents the lineage or chain of germ-cells; B^2, B^3, B^4 are the bodies of three successive generations which fall off from the chain. The fundamental idea is that a fertilised egg-cell gives rise to a body *and* the germ-cells of that body.

intact and unspecialised to form the beginning of the reproductive organs of the offspring, whence will be launched in due course another organism on a similar voyage of life. The reproductive cells of any organism are the outcome of embryonic cells which did not share in the upbuilding of that organism, but continued the germinal tradition unaltered. This is suggested clearly in a diagram slightly modified from one devised by Professor E. B. Wilson. Thus the parent is rather the trustee of the germ-plasm than the producer of the child. In a new sense the child is a chip of the old block. The old question was: Does the hen make the egg, or the egg the hen? The modern answer is that the fertilised egg makes the hen *and the eggs thereof*. The fact of germinal continuity explains the inertia of the main mass of the inheritance, which is carried on with little change from generation to generation. Similar material to start with; similar conditions in which to develop; *therefore* like tends to beget like. As Professor Bergson puts it, "life is like a current passing *from germ to germ* through the medium of a developed organism."

§ 9

As regards Selection.

When we are interpreting the past history of animals, we utilise factors which are seen in operation to-day, just as the geologist does when he is interpreting scenery. It is satisfactory, therefore, that post-Darwinian investigations have *demonstrated* some modern instances of selection *at work*. Let us take a simple case. The Italian naturalist Cesnola tethered some green Mantises with silk thread on green herbage, and found that they escaped the eyes of birds. Similarly, when the brown variety was tethered on withered herbage. But green Mantises on brown herbage and brown Mantises on green herbage



MENDELIAN INHERITANCE IN ANDALUSIAN FOWLS.

(*After Darbishire.*)

P, the parents, black (dominant) and white (recessive).

F1, the hybrid generation, "blue" Andalusians, illustrating imperfect dominance.

F2, the second filial generation: 25 per cent. pure blacks ("extracted pure dominants"), DD; 50 per cent. "blues" (impure dominants), D(R); and 25 per cent. whites (extracted recessives), with occasional black spots (RR).

HALF-LOP RABBIT.

A half-lop rabbit, after Darwin, an instance of a variation which seems to be rather uncertain in its inheritance. The peculiarity is that one of the ears hangs down, whereas in "full-lops" both ears do. The pendent ear is often broader and longer than the upright one, an unusual asymmetry. Darwin noted that when the half-lopped condition occurs, whether in one parent only or in both, there is nearly as good a chance of the progeny having both ears full-lop as if both parents had been full-lopped.

were soon picked off. Discriminate selection was at work.

When we are concerned with making a good lawn we may pursue two methods. We may eliminate the weeds or we may foster by suitable tonics the growth of the grass. Similarly, in Nature's sifting there is *lethal selection*, which works by eliminating the relatively less fit to given conditions of life, and there is *reproductive selection*, which works through the predominant increase of the more successful. Darwin never thought simply of Natural Selection; he always emphasised its manifold and subtle modes of operation. He saw, for instance, what some of his successors missed, that the sifting need not in the least involve a sudden cutting off of the relatively less fit, for a shortened life and a less successful family will in the long run bring about the same result as a drastic pruning. It should not be necessary to point out that "the survival of the fittest" does not *necessarily* mean the survival of the strongest or cleverest or best; it simply means "fittest" relatively to particular conditions. The tapeworm is a fit survivor as well as the Golden Eagle.

Darwin realised what some of his successors have missed, that even slight peculiarities may be of critical moment when tested in relation to the complex web of life in which the creature has its being. This is very important in regard to the general progressiveness of evolution—that new departures are sifted in reference to a slowly wrought out and firmly established system of inter-relations. (See the article on Inter-relations.)

§ 10

Sexual Selection.

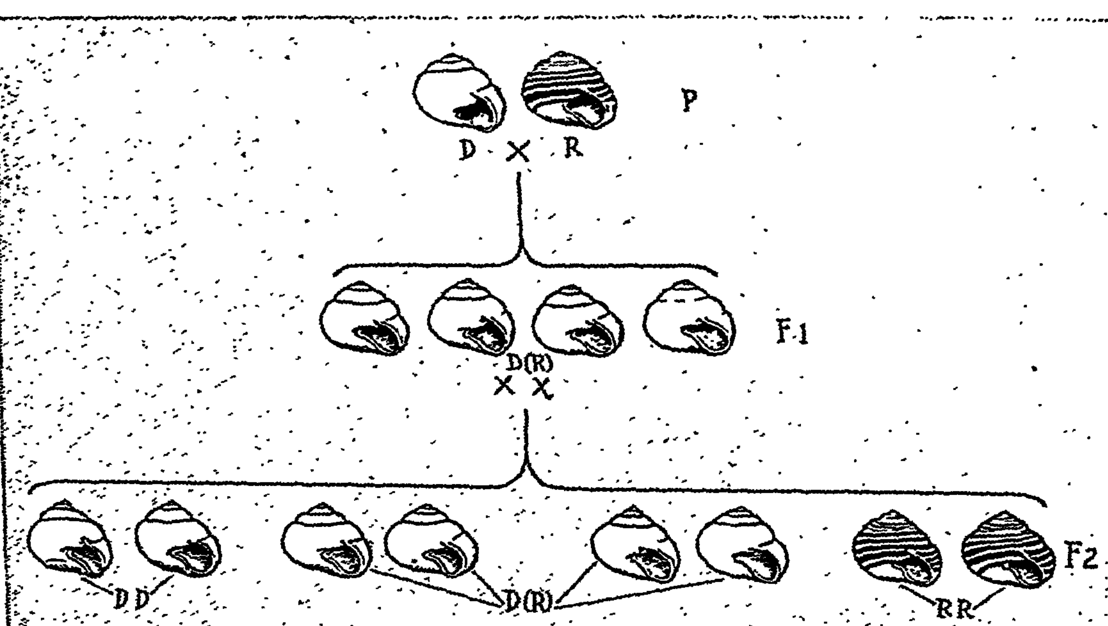
Many male animals, such as stags, antelopes, sea-lions, black-cock, and spiders, fight with one another at the mating time, competing for the possession of females. According to Darwin, "the strongest and, with some species, the best-armed of the males drive away the weaker; and the former

would then unite with the more vigorous and better-nourished females, because they are the first to breed. Such vigorous pairs would surely rear a larger number of offspring than the retarded females, which would be compelled to unite with the conquered and less powerful males, supposing the sexes to be numerically equal; and this is all that is wanted to add, in the course of successive generations, to the size, strength, and courage of the males, or to improve their weapons" (*Descent of Man*, 2nd ed., p. 329). Similarly, there would be a premium on those male characters that are useful in the recognition and capture of the females, e.g. large olfactory feelers in moths and strong claspers in skates.

The term "sexual selection" was used by Darwin to include all forms of sifting in connection with mating, but prominent among these was the preferential behaviour of the female. "Just as man can give beauty, according to his standard of taste, to his male poultry . . . so it appears that female birds in a state of nature have, by a long selection of the more attractive males, added to their beauty or other attractive qualities." In the courtship, which is often elaborate, the female selects—in a literal sense.

Darwin was well aware of difficulties besetting his theory of sexual selection, and his fellow-worker Alfred Russel Wallace was one of his severest critics. There has to be proof that some of the males are actually disqualified and left out in the cold. But Darwin indicated that the sifting would work even if the less successful males were not entirely eliminated. Moreover, in some cases the female's preference goes to great lengths; thus a female spider often kills a suitor who does not please her.

It is difficult, again, to prove actual "choice" on the female's part. But there are undoubted cases of preferential mating, whatever the psychology of the process may be. Some critics, like Wallace, have pointed to the difficulty of crediting the female with a capacity for appreciating slight differences in the decorativeness, agility, or musical talent of her suitors. But the modern answer is simply that the accepted mate is the one that most strongly evokes the



INHERITANCE IN SNAILS, WITH BANDLESS AND BANDED VARIETIES.

(*After Lang.*)

When bandless Wood-Snails (*Helix nemoralis*) or bandless Garden Snails (*Helix hortensis*) are crossed with banded individuals of these species, each will make a nest in the ground and deposit half a hundred eggs or more. A snail is always *hermaphrodite*, producing eggs and sperms; but the eggs of one snail (banded, let us say) are fertilised by the *sperms of another snail* (bandless, let us say). Let us follow the eggs of a banded individual, *fertilised* by the sperms of a bandless individual snail. They will develop into individuals whose shells are all bandless, D(R). The negative quality "bandless" (D) is dominant; the positive quality "banded" (R) is recessive. If the bandless hybrids (F_1) pair together, the offspring (F_2) will be: 25 per cent. pure bandless—extracted *dominants* (DD); 50 per cent. impure dominants, D(R), in appearance bandless; and 25 per cent. pure banded—extracted recessives (RR). If we had started with the eggs of a bandless individual, fertilised by the sperms of a banded individual, the result would have been the same.

pairing instinct, and that it is not necessary to credit the female with any analytic weighing of the merits of the various males. The details must count, if there is anything in the theory, but they may count, not as such, but as contributing to a general impression of interesting attractiveness.

To point out that certain masculine features, such as antlers, are congruent with the male constitution, just as certain feminine features, such as functional milk-glands, are congruent with the female constitution, is getting behind the question of selection to that of the origin of the variations which form the raw materials of the sifting process—an interesting line of inquiry which has been followed by Geddes and Thomson in their *Evolution of Sex*.

Another important consideration arises when we think of the frequent intricacy and subtlety of the courtship habits (see Pycraft's *Courtship of Animals*). There must be some deep racial justification for this. Groos has suggested that the female's coyness is an important check to the male's passion, which tends to be too violent. Julian Huxley has suggested from his fine study of the Crested Grebe that the courtship ceremonies establish emotional bonds which keep the two birds of a pair together and constant to each other.

§ II

CONCLUSIONS

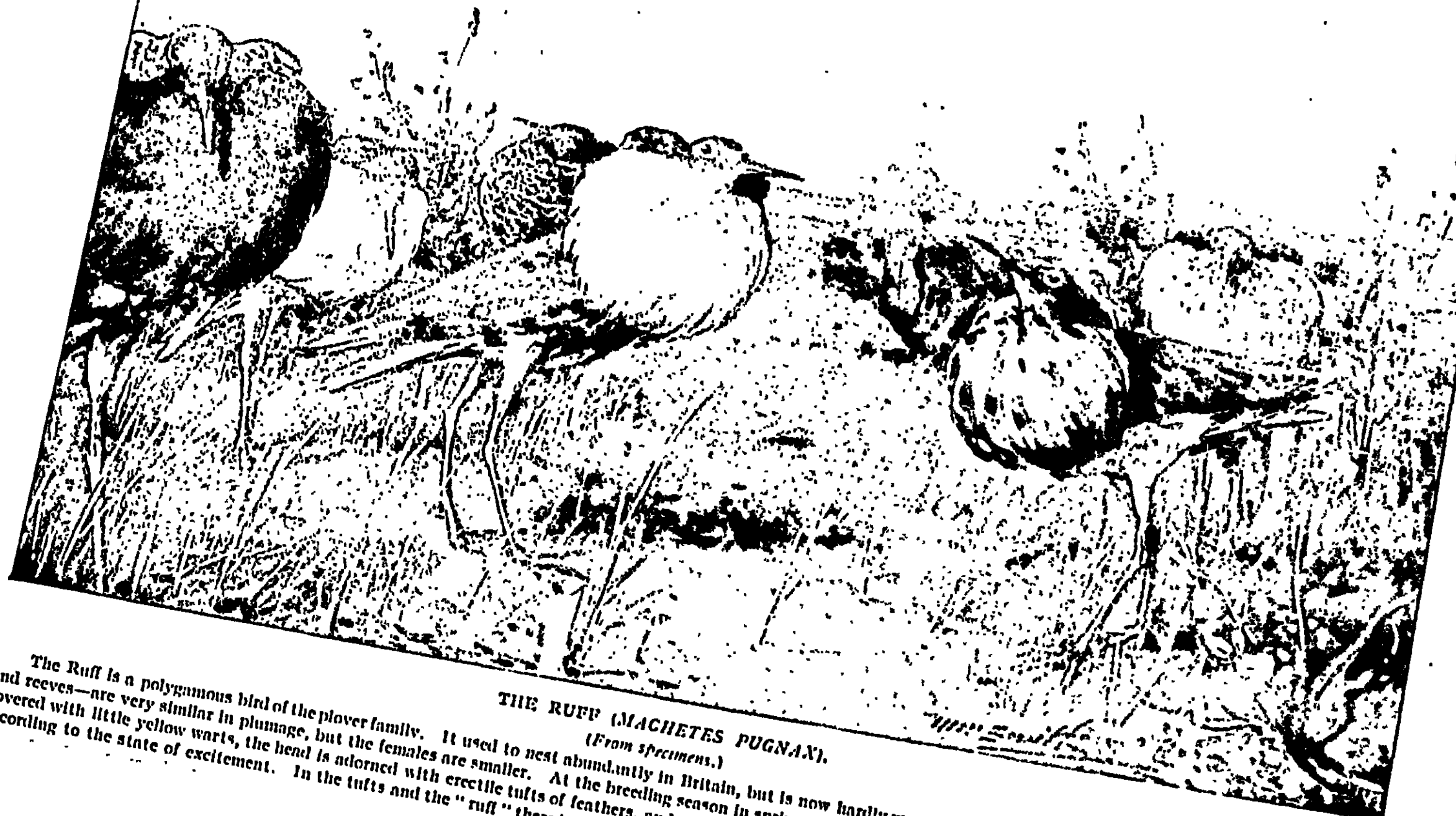
1. If Darwinism means the general idea of evolution or transformism—that higher forms are descended from lower—then it stands to-day more firmly than ever.

2. If Darwinism means the particular statement of the factors in evolution which is expounded in *The Origin of Species*, *The Descent of Man*, and *The Variation of Animals and Plants under Domestication*, then it must be said that while the main ideas remain valid there has been development all along the line. Darwinism has evolved, as every sound theory should.

3. In regard to the raw materials of evolution, there is greater clearness than in Darwin's time as to the contrast between intrinsic variations of germinal origin and bodily modifications imprinted from without, and there are grave reasons for doubting whether the latter do as such affect the race at all. There is still to be heard the slogan "Back to Lamarck!" but there can be no return to any crude Lamarckism. If the individual gains and losses, the individual indents and prunings, really count as such in racial evolution, it must be in some subtler way than is suggested by the giraffe getting its long neck by ages of stretching, or the deep-sea fish becoming blind by generations of darkness and disuse. There should be no haste to close any door of reasonable interpretation, still less of experimental inquiry, but there is at present amongst zoologists widespread agreement with Sir Ray Lankester's pronouncement that one of the notable advances since Darwin's day has been getting rid of the Lamarckian theory of the transmission of individually acquired characters or imprinted bodily modifications. Of course, counting of heads is no argument; but the facts are not at present in favour of the Lamarckian view. But we may perhaps look for an evolution of Lamarckism as well as of Darwinism!

4. Darwin based his theory of evolution very deliberately on the fluctuating variations which are always occurring. Given time enough and a consistent sieve (the struggle for existence), will not Nature achieve more or less automatically what man reaches purposefully in his breeding of cattle and cultivating of wheat? But modern Darwinism, while holding fast to this, welcomes the demonstration that brusque discontinuous variations or mutations are common, and that they are very heritable. All of a sudden, it appears, the sporting Evening Primrose may produce an offspring which is potentially a new species.

5. Darwin meant by "fortuitous variations" that he could not give any formula for the causes of the novelties he observed. No doubt he also meant that the organism in varying was not aiming at anything. And yet he laid great stress on what he called "the principle of correlated variability"—an idea of great importance—that when one part varies other parts vary with it, "being members one of another" as St. Paul said. In other words, a particular germinal change may have a number of different outcrops or expressions. But the more correlation there is, the less reasonable will it be to speak of fortuitousness. And one of the changes since Darwin's day is the recognition that variations



THE RUFF (*MACHETES PUGNAX*).

(*From specimens.*)

The Ruff is a polygamous bird of the plover family. It used to nest abundantly in Britain, but is now hardly more than a bird of passage. In winter the two sexes—ruffs and reeves—are very similar in plumage, but the females are smaller. At the breeding season in spring there is very marked sex-dimorphism. The face of the male becomes covered with little yellow warts, the head is adorned with erectile tufts of feathers, and the fore-neck develops a large "ruff" of feathers which can be raised and depressed according to the state of excitement. In the tufts and the "ruff" there is extraordinary variability of colouring, e.g. white, rufous, or black, with or without bars. It is said

are often very definite—just as they are among crystals.

6. Another change from Darwin is the Mendelian idea of unit-characters, which behave like entities in inheritance. They are handed on with a strong measure of intactness to a certain proportion of the offspring. Their "factors" in the germ-cells are either there or not there. Sometimes, at least, these unit-characters arise as mutations, and thus we have an answer to Darwin's difficulty that abrupt changes would be averaged off in intercrossing. Unit-characters do not blend.

7. Since Darwin's day there has been, in a few cases, definite proof of natural selection at work; the different forms of selection have been more clearly disentangled; the subtlety of Darwin's idea of selection has been confirmed; the reality and the efficacy of preferential mating has been much criticised, but Darwin's theory of sexual selection has in its essentials weathered the storm. In proportion as new departures come about suddenly by brusque mutation, the burden to be laid on the shoulders of selection will be lessened. In so far as the selection is in relation to a previously established system of inter-relations, there will be a reduction of the fortuitous in the process; and the same will be true in proportion to the degree in which the organism takes an active share in its own evolution—as it often does.

8. Modern biologists are inclined to put more emphasis on "Isolation" than Darwin did, meaning by "Isolation" all the ways in which the range of intercrossing is restricted and close in-breeding brought about.

When we use the term Darwinism to mean, not his very words, but the living doctrine legitimately developed from his central ideas of variation, selection, and heredity, we may say that Darwinism stands to-day more firmly than ever. It has changed and is changing, but it is not crumbling away. It is evolving progressively.

This is only an "outline" of a great subject, and it is not an article that he who runs can read. It is very important to avoid dogmatism in regard to an inquiry which is still relatively young. There was not much scientific evolutionism before Darwin's day. The writer has not concealed his opinion in regard to such a question as the transmission of acquired characters, but it is not suggested that this is the only possible opinion. It may be recommended that readers to whom the subject is comparatively new, and to whom it appears full of uncertainties, should write out their ideas in a definite way and then compare them carefully with the relevant paragraphs in the article. It is all too easy to go off on a wrong tack, and this should be guarded against by patient study. For the problems of evolution are fundamental.

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XII
NATURAL HISTORY

I. BIRDS

IN previous chapters of this book we have discussed the evolution of animals in general, the inclined plane of behaviour and the everyday life of the body, and it has been necessary to make many references to birds. But there are good reasons for devoting a special chapter to this great class. Birds have entered closely into human life, and in manifold ways. They supply food, and they are the poet's symbols. Their feathers keep us warm at night, and wing the arrow of the bowman. Birds save the world from the continual menace of prolific insects, and they gave the priests a basis for their auguries. To birds we must trace the enormous nitrate beds of Chili which have fertilised the soil of half the world, and we may thank them too for a share in the impulse that has led man to his mastery of the air. Moreover, most birds are joys for ever. Biologically regarded, birds are of supreme interest in their solution of the problem of flight—so different from that of insects, Pterodactyls, and bats; in their variability and plasticity within a comparatively narrow range; and in their fascinating behaviour with its remarkable blending of instinctive and intelligent activities.

§ 1

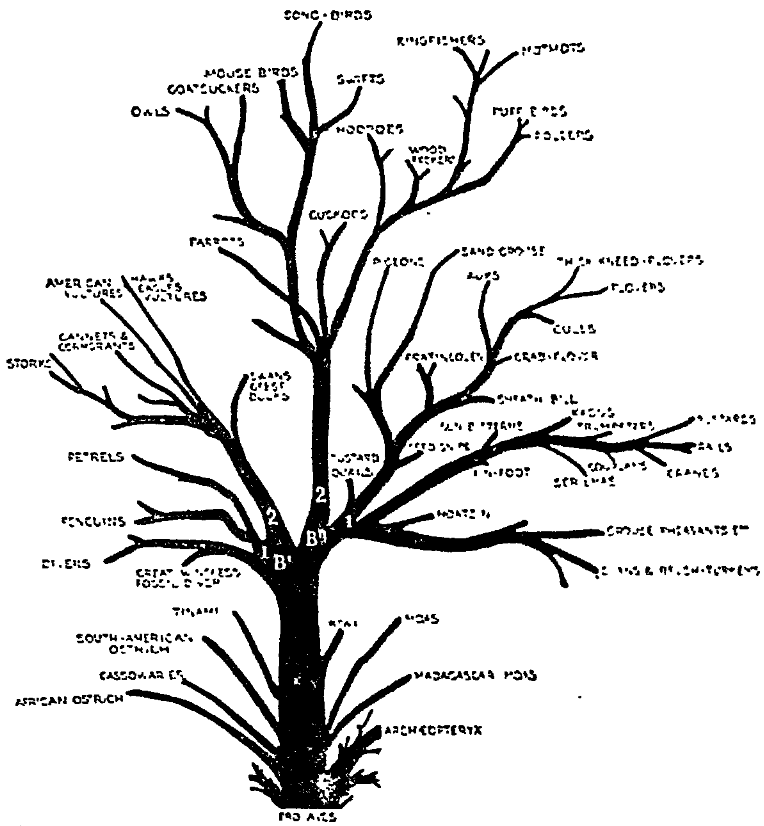
Millions of years ago the evolution of bird from a reptilian stock began, as has been already described in an early chapter of this work. At first sight it is not easy to see any resemblance between Birds and Reptiles, the one group warm-blooded, conspicuously active, and gloriously beautiful, the other cold-blooded, often sluggish, but perhaps also beautiful in their way. What kinship can there be between the falcon in the sky and the lizard on the wall? The student of comparative anatomy answers that the evidences of similarity are overwhelming: bone by bone the two creatures are built up on a plan that is certainly to a very great extent the same, however much the final products may be modified and adapted. Without much preliminary study of anatomical structure, these points might be difficult to apprehend and appreciate, and we cannot discuss them here; we must accept the verdict of the experts, and admit that birds are the descendants of a reptilian stock—not necessarily of any present-day group of reptiles, but rather of a common ancestor in the immensely remote past. Just one simple point of similarity between the two groups may be mentioned, the fact that both lay eggs, and eggs which are indeed closely alike in several respects.

Photo: Royal Scottish Museum.

MODEL OF THE EXTINCT DODO.

The Dodo was a large flightless pigeon inhabiting Mauritius. It became extinct in the sixteenth century soon after the arrival of Dutch sailors on the island: the pigs which these men brought with them played a large part in the extermination.

We may imagine the ancestral forms as small lizard-like



After W. P. Pycraft.

THE EVOLUTION OF BIRDS.

A diagrammatic attempt to express the relationship of the main groups of present-day birds, based on a study of structural affinities. The main stock is shown as arising from the ancestral "Pro-Aves," akin to the ancient Reptiles. Offshoots low down represent the extinct Archaeopteryx and the different Ostrich-like birds, present and recent. Higher up two main branches (B′, B″) are shown, each of them dividing again into two (1, 2; 1, 2) and then into the twigs representing the various groups.

animals, making the first beginnings of the kind of life which we see to great perfection in the birds of to-day. Real power of flight would at first be absent among these early ancestors, but we may think of it as foreshadowed by a great power of leaping from branch to branch in the trees of the primeval forest, where these far-off ancestors of our birds had taken refuge from their terrestrial enemies. We may picture them as making the most of their arboreal haunt, probably using holes in the tree-trunks in which to hide and to lay their eggs, and gradually developing a greater and greater agility in moving about above ground in search of food, and in escape from such enemies as were still able to molest them.

The Dawn of Bird-Life.

This mode of life would tend, generation after generation, to produce strong propelling hind-limbs, together with fore-limbs, armed with hook-like claws useful for taking hold at the end of each jump and for more leisurely clambering at other times. The crucial step in the evolution of the true bird stock, however, must have been the acquisition of powers of real flight. At an early stage the fore-limbs would be held out sideways during each leap, and later the surface area would become enlarged by the development of a fold of skin between each of these limbs and the body. Later yet this fold would become still more important, and its area would be still further increased by the transformation of its covering scales into some primitive form of feather. Longer and longer leaps would become possible, from branch to branch and from tree to tree, as these aids to gliding flight improved. Finally, the last great step would be taken when a beginning was made of the active use of the primitive wings to prolong still further, until at last indefinitely, the distances possible by leaping and gliding alone.

It is a curious history, this tale of the origin of birds. In the first place we seem to see the earliest ancestors as a feeble reptilian race driven from the ground and taking refuge among the branches. There followed ages of arboreal life during which the great adaptation of flight originated and was made perfect. Then came a day when the new race of birds, fortified with the great advantage of mastery of the air, spread abroad from the forests—to reconquer the ground-level, to find their bread upon the waters, to cross the seas to distant isles, and to defy the rigours of climate by their ability to

"change their season in a night." So to-day we have birds peopling the whole earth and filling every land with the abundant beauty of their plumage and their song, and with the immense wonder of their eager, spirited lives.

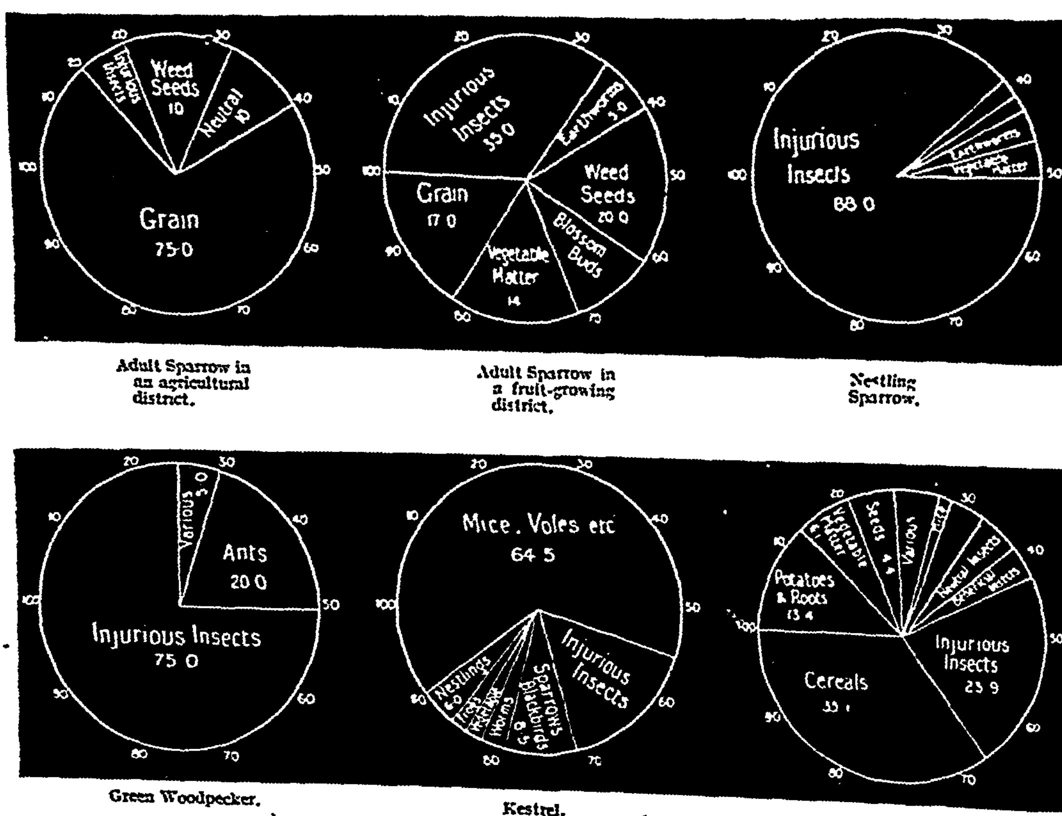
§ 2

Flightless Birds.

It is a strange side-issue, too, to find that the priceless gift of flight has not always been preserved. Over and over again since the reconquest of the ground-level, there have been birds which have discarded the faculty which was the making of their race; over and over again, also, they have paid the extreme penalty. Sometimes size and strength, sometimes an aquatic life, sometimes an island home, has been the factor giving security in place of flight, but with new conditions the exchange has frequently proved to be unfortunate: too often, in recent cases, the new condition has been the advent of modern Man and his civilisation.

Several flightless species are indeed numbered among the birds which have become extinct within historic times. Among the Maoris of New Zealand there was a traditional knowledge of a giant running bird which they called "Moa," but which they had exterminated before the arrival of white men; from the bones and other remains which have been found in some quantity the birds appear to have been large members of the Ostrich tribe, one species standing 12 feet in height. A related bird of similar history was the Æpyornis of Madagascar, which forms the subject of the delightfully imaginative story by Mr. H. G. Wells. This bird is sometimes identified with the legendary "Roc" of the *Arabian Nights*; not only its remains but also its eggs have been found, and an egg in the British Museum (Natural History) measures more than 13 inches in length and 9½ in breadth.

"Extinct as the Dodo" has become a proverbial expression. The saying refers to a bird allied to the Pigeons, about the size of a Swan,



BIRDS AND THEIR FOOD.

This diagram illustrates to what extent certain birds are harmful or useful in respect of our food crops. The evidence is obtained by examining the bird's crop or gizzard at the time of death. The calculations were based on statistics published by Dr. Collinge in the *Journal of the Board of Agriculture*.

and of clumsy and uncouth appearance. It was quite flightless, and lived in security in Mauritius until the island was visited by Dutch sailors in the sixteenth century. The hogs which these men brought with them were largely responsible for the subsequent rapid extermination of the birds, and now

The Dodo.

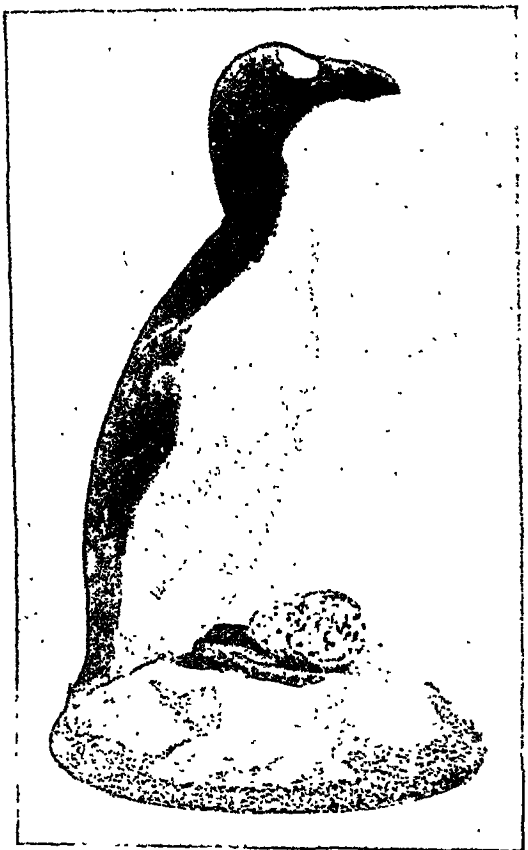


Photo: Royal Scottish Museum.

GREAT AUK (WITH EGG).

A large flightless species related to the Razorbill and the Guillemot. It became extinct about the middle of last century, but was formerly common on the coasts of Iceland and Newfoundland and not unknown in British waters. Specimens and eggs are much prized rarities nowadays, and will command several hundred pounds if in good condition.

the Dodo is known only from some remains in museums and from the quaint drawings and descriptions of the early voyagers.

Among the birds of the present day, the Ostrich tribe and the Penguins are the principal examples of flightlessness. The Ostrich and its kin are for the most part birds of large size, possessing a soft, hair-like plumage, diminutive wings, and strong legs; they are capable of running at great speed across open country, and also of kicking with suddenness and force. Their breastbones lack the pronounced "keel" which is so noticeable in most birds, and which serves for the attachment of the great muscles for working the wings in flight. Best known, of course, is the African Ostrich, now being domesticated by man for the sake of its plumes, but there are also several kinds of American Ostriches or Rheas in South America, and of Cassowaries and Emus in Australasia. Unlike their fellows are the Kiwis of New Zealand, birds of no great size, timid and nocturnal in habit; their long beaks and their hair-like plumage combine to give an exceedingly quaint appearance, and there are no visible wings.

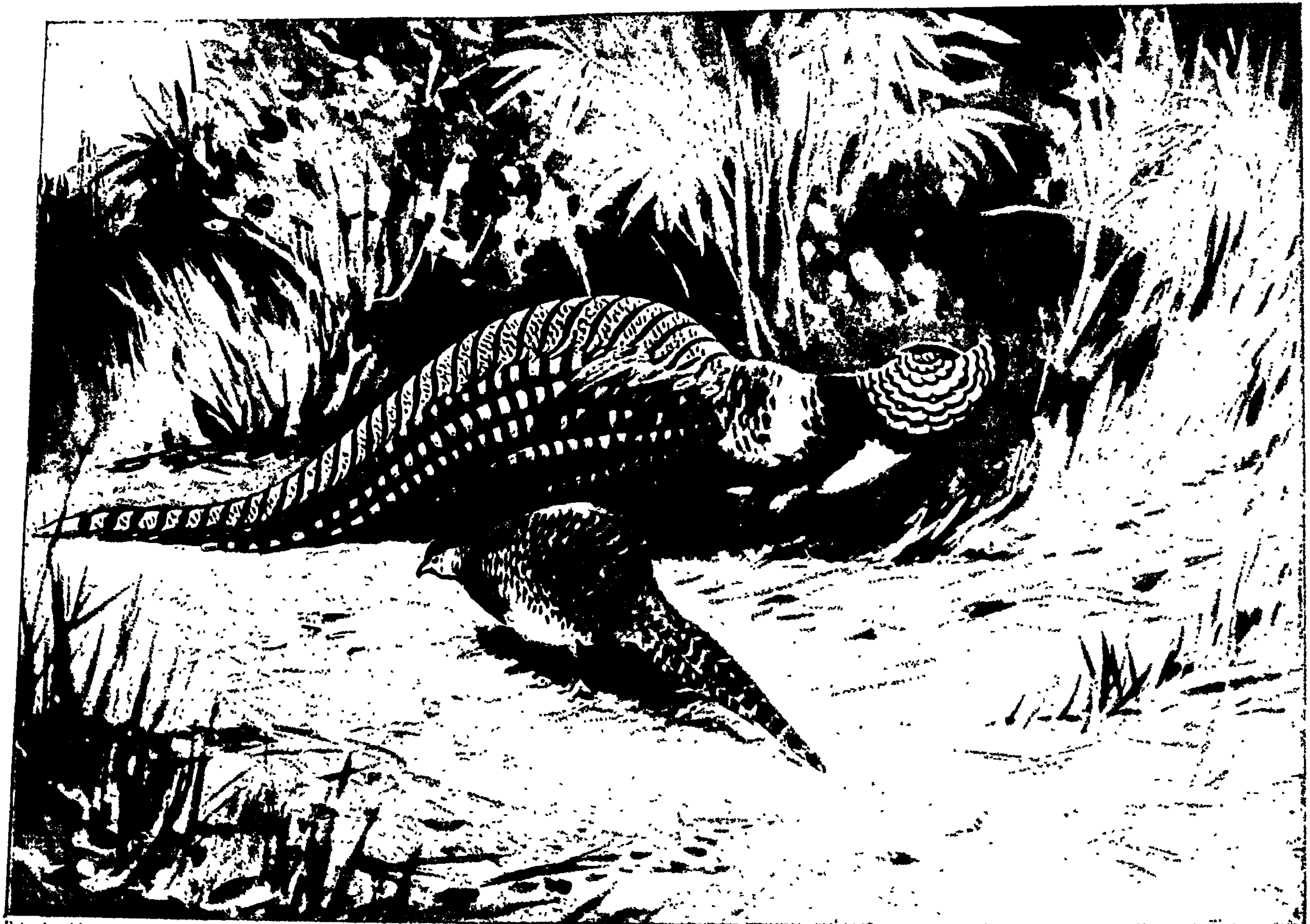
The Ostrich Tribe.

The Penguins are rather a different case, for their wings have by no means fallen into disuse; they have become, instead, adapted for swimming. There are many different kinds, but all belong to the Southern Hemisphere, and most of them to the far south. Many Antarctic explorers have brought back tales of their life, but it is to Dr. Murray Levick, who was with the *Terra Nova* in 1910, that we owe one of the best accounts, relating particularly to the Adélie Penguin. These flightless birds will return, "over hundreds of miles of trackless sea," to the same "rookeries" year after year to breed. Dr. Levick describes how the first penguin arrived at the "rookery" at Cape Adare towards the middle of October, the southern spring, and how four days later the birds were coming in across the still unbroken sea-ice in such numbers that they formed a line stretching northwards as far as the eye could see; within a month the colony was some three-quarters of a million strong.

Penguins.

The Adélie Penguin builds a large nest of stones, the only material available, and the uses of this are evident when the thaw comes and the ground is covered with water and slush. In this nest two large eggs are laid, and one of the parents goes off to the sea to feed while the other remains to incubate. The bird which leaves may be away for a week or ten days, and the other may therefore not break its fast for as much as four weeks in all.

"I know of no other creature," says Mr. Herbert G. Ponting, "from which man may



Reproduced by courtesy of Messrs. Methuen & Co. from "A History of Birds," by W. P. Pycraft. (After a painting by G. E. Lodge.)

THE AMHERST PHEASANT IN DISPLAY

learn a finer lesson of how resolution and steadfastness may overcome every difficulty than from the Adélie Penguin." Their bravery is amazing; no blizzard, however violent, will drive these birds from their nests in the wild Antarctic regions. Mr. Ponting relates that they are found sitting on their nests buried deep in the snow. Wondering where the birds had disappeared to after a blizzard, he set out to investigate. "As I was struggling about, wondering whether my penguin investigations had come to an abrupt end, I was almost 'scared out of my life' by a muffled squawk, and felt something wriggling under my foot. I had stepped on the back of a sitting penguin—buried nearly two feet deep in the snow. As the victim struggled out, loudly protesting its wrath at this outrage, we were convulsed with laughter; then, roused by our noisy mirth, scores of black heads, with 'gollywog' eyes, suddenly protruded from the snow—to see what all the fuss was about. That was how we discovered them! They had *not* deserted the place; but were attending to their domestic duties *under* the snow—patiently waiting for it to blow away. There were penguins everywhere; it was impossible to walk without stepping on them."

The penguins are fond of all manner of amusements; leaving their young under the protection of a few of the old birds, most of the parents go off to disport themselves on the ice or in the water. "They will string out behind a leader and make for the near ice-floes, the party sometimes porpoising along the water, then tobogganing over the ice. They followed in a line behind the leader, doing exactly as he did. The fun became fast and furious, and I suppose they got a bit winded, for after a while the courier gave them a rest. Following his lead they sprang on to an ice-raft; then, still imitating his example, they settled down on their breasts and basked awhile in the sunshine—prior to doing a few more laps. That they all thoroughly enjoyed the game, there could be no possible doubt." [1]

The Emperor Penguin is the largest species and may stand over four feet high. Unlike the Adélie it nests, or rather lays its single egg, on the sea-ice itself, and it is remarkable for breeding in mid-winter.

The Emperor Penguin.

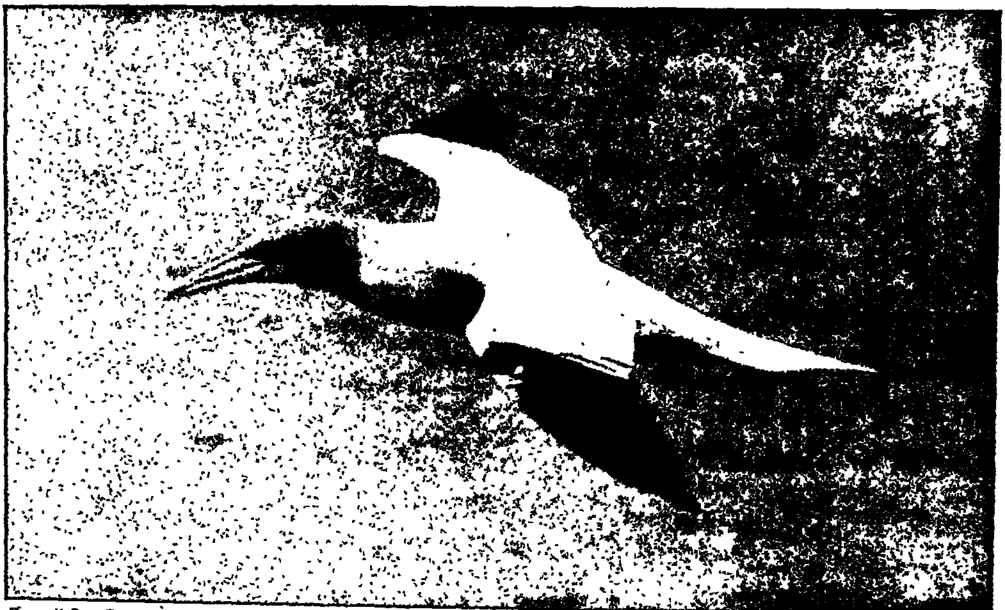
Incubation lasts for as much as six or seven weeks, but the task is shared, not only by both parents, but by the strangely large number of barren birds living in the colony. The chick has the rather doubtful advantage of a number of foster-parents all desirous of participating in its care, a strange condition of things which was well described by Dr. A. E. Wilson, who afterwards shared Scott's tragic fate on the return journey from the Pole: "What we actually saw, again and again, was the wild dash made by a dozen adults, each weighing anything up to ninety pounds, to take possession of any chicken that happened to find itself deserted on the ice. It can be compared to nothing better than a football 'scrimmage' in which the first bird to seize the chick is hustled and worried on all sides while it rapidly tries to push the infant between its legs with the help of its pointed beak, shrugging up the loose skin of the abdomen the while to cover it. That no great care is taken to save the chick from injury is obvious from an examination of the dead ones lying on the ice. All had rents and claw-marks in the skin, and we saw this not only in the dead but in the living. The chicks are fully alive to the inconvenience of being

Photo: James's Press Agency.

THE KIWI OR APTERYX.

A small member of the Ostrich tribe, found in New Zealand. It is not only flightless, like its relatives, but also lacks visible wings. It is a shy bird of nocturnal habits: the beak, used for probing, is long and sensitive; the legs are powerful; the plumage is long and hair-like.

[1] H. G. Ponting, *The Great White South.*



From "Our Common Sea-Birds" (Country Life, Ltd.).

GANNET—A LESSON FOR AVIATORS.

fought for by so many clumsy nurses, and I have seen them not only make the best use of their legs in avoiding such attentions, but remain to starve and freeze in preference to being nursed. Undoubtedly, I think that of the 77 per cent. that die before they shed their down, quite half are killed by kindness."

§ 3

Flying Birds.

With this strange and rather terrible picture of the early life of the Emperor Penguin amid the rigours of the Antarctic climate and on the naked ice of the frozen sea, we may turn from flightless to flying birds. The flightless birds, indeed, represent digressions from the main line of descent, and cannot be regarded as stages in the evolution of modern flying birds from the ancient forms which first mastered flight in the forests of long ago.

Birds share with mammals the distinction of being "warm-blooded," that is to say, having a high and constant body temperature independent of surrounding conditions. We may take this as an index of a high degree of vitality and of an advanced position in the evolutionary scale, and we shall indeed find many other features which lead towards the same conclusion. Birds are noteworthy for alertness of mind and body, for quickness of movement, and for their mastery of the air. They have highly developed habits and complex instincts: they are in turn combative, amatory, parental, cunning in pursuit and escape, and in very many cases there is a surpassing beauty of plumage and voice which compels our intense admiration.

"Beast" is one of those words of variable and confused sense which drive men of science to use a language of their own, but the term "bird" scarcely needs to be defined, for its everyday meaning is also scientifically accurate. This fact may perhaps be attributed to the existence of certain very distinctive characteristics common to all birds, and to a large measure of uniformity in general appearance among the nearly twenty thousand different species which are known to science; there are, it is true, wide differences in size, in coloration, and in manner of life, but there are no gross divergences in form comparable to those found, for instance, among mammals—between the tiger and the goat, the kangaroo and the elephant, or the bat and the whale.

This distinctiveness and this uniformity may both be accounted for in one word—Flight. The whole body of the bird is adapted to this habit of flying. The bird's skeleton is a wonderful study from this point of view, but here it will suffice to mention the external features.

Flight has brought with it feathers, and these are a unique feature: all birds have feathers, and nothing that is not a bird possesses any trace of them. Furthermore, the function of flight has secured a virtual monopoly over the fore-limbs, and it has thus brought two other striking adaptations in its train—a bird is of necessity a biped, walking on its two hind-limbs, and its mouth has had to take the place of a hand, thus leading to the evolution of a long flexible neck, and of a hard beak which is often wonderfully adapted to the feeding habits of the particular species.

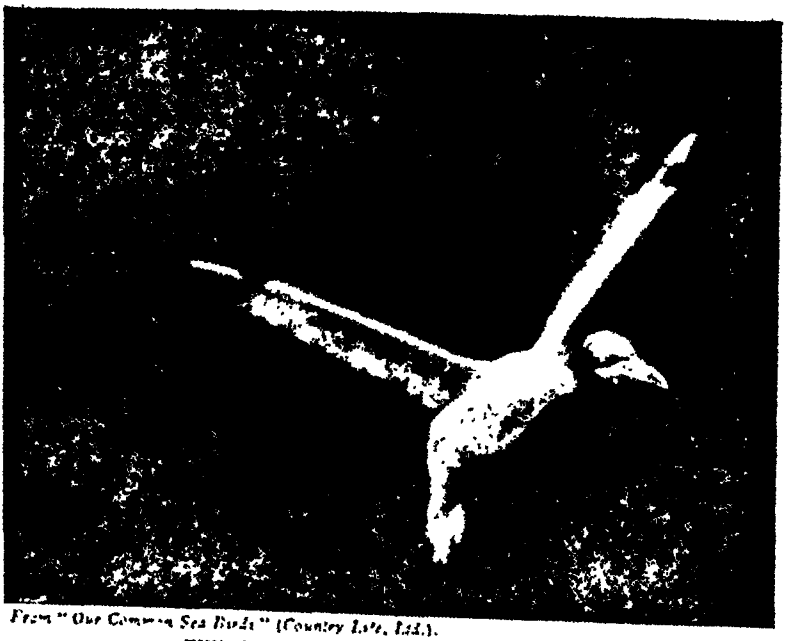
§ 4

The Flight of Birds.

Birds are, of course, true heavier-than-air machines, and in former days man used to strive to learn their secret for the purposes of the flying-machines which his heart desired; but within the last few years the main physical principles of the aeroplane have become so familiar that we may perhaps reverse the process by using them in the description of our present problem! Just as gliders preceded aeroplanes, so gliding flight may, as we have seen, have been the beginning of the mastery of the air in the case of birds; and it is in gliding that the artificial machine and the bird are most alike. In both cases advantage is taken of the resistance of the air, and of the consequent upward tendency imparted to a body moving horizontally and having a flat inclined under-surface.

When we come to active flight a difference is at once obvious: the aeroplane propellers supply a motive force independently of the planes, while in the bird the wings are both propellers and planes at the same time. There is, indeed, a further difference in that the aeroplane's propellers, during level flight at least, exert force purely in a horizontal direction, the lifting force being wholly due, as in gliding, to air resistance. In the bird the wing-strokes themselves supply part of the lifting power, as well as propelling the body forwards. Nor must we forget the bird's tail, which plays a part in steering and balancing as in the case of the aeroplane rudder; it is also often used as a brake, without which many a swiftly pouncing bird of prey would be apt to dash itself to destruction on the ground.

Some of the larger birds are adepts at soaring, and can remain in the air for a long time with motionless wings, and can even rise in slow spiral ascent to a great height. The late Mr. F. W. Headley, a keen and exact student of the flight of birds, came to the conclusion that this feat was inexplicable except on the supposition that advantage was taken of up-currents in the air, the bird's actual motion being merely a gliding one. He pointed out that gulls are adepts at this when flying above the edge of a cliff, but that they cannot do it at sea, where, as aviators and air travellers know, there are not the vertical disturbances caused by the varying ground-level temperature and by the changing elevation of dry land. Another feat, namely hovering, is familiar in the hunting methods of the Kestrel, which maintains a stationary position for an



From "Our Common Sea Birds" (Country Life, Ltd.).

THE GANNET—PUTTING ON THE BRAKE

"The instant fish are detected swimming close to the surface, the Gannet comes wheeling round; down go the brakes 'hard all'; its depressing planes are tilted; it sweeps downwards, half closing its wings, and then falls like a streak of white light, plumb to the water"—and there is one fish less in the sea.

appreciable time. Against a strong wind it would be easy to maintain a *ground* speed of *nil*, and it would be possible even with motionless wings. In still air, however, the ordinary gliding basis of flight is in abeyance, and altitude must be maintained by sheer vertical force of wing-stroke, the bird being thus more nearly equivalent to a helicopter than to an aeroplane.

From "Our Common Sea-Birds" (Country Life, Ltd.). *Photo: J. C. Douglas.*

HERRING-GULLS (*LARUS ARGENTATUS*).

The Herring-Gull gets its name from its habit of following shoals of herrings. The Gulls will follow shoals of small fish swimming near the surface. They usually swoop down upon them on a flat curving course, not submerging the body but merely immersing the head and bill.

The aviators of to-day compete to establish records for speed, for endurance, and for altitude.

Speed and Altitude.

How do birds stand in these respects? As regards speed, in the first place one must remember the difference between "ground speed" and "air speed." Both the aeroplane and the bird can, for a certain expenditure of power, attain a certain velocity in the body of air in which they are, but the velocity as measured from the ground may be a very different thing. Thus an aeroplane travelling at 100 miles per hour in a 20 miles per hour wind may seem from the ground to be going at 120 miles or at 80 miles per hour, accordingly as it flies with or against the air-stream; so also, of course, with the bird. All our speed records of birds, except a few made from aeroplanes, are necessarily in terms of ground speed, and in many cases the particulars necessary for a wind correction are unhappily wanting.

What are some of the actual figures? The available evidence has recently been summarised by Colonel Meinertzhagen, with special reference to speed during migration; he concludes that a bird has an ordinary pace, which is the one used in migratory flight, and an accelerated pace of which it is capable for a short distance under stress of danger or in other special circumstances. Here are some of his figures: carrier-pigeons, 30–36 miles per hour (over 60 has been recorded, but possibly only with a strong favourable wind); crows, 31–45; small song-birds, 20–37; starlings, 38–49; ducks, 44–59; he also quotes the case of a flock of swifts flying at 6,000 feet above Mosul, in Mesopotamia, which in their ordinary flight easily outpaced the observer's aeroplane when it was doing 68 miles per hour. The air speed of this astonishing flyer is, when accelerated, probably well over 100 miles an hour.

As regards altitude, it seems that although birds have occasionally been recorded as high as 15,000 feet, they are indeed rarely met with above 5,000 feet, while the greater part of flight, including migration, probably takes place within 3,000 feet of the ground.

§ 5

The power of flight has given birds the key to one kind of habitat after another that might otherwise have proved to be too dangerous or

too inhospitable. To the conditions of these different haunts, and, in particular, to different modes of procuring food, we see a great wealth of adaptations: there are hunters and fishers, catchers of insects and harvesters of seeds, eaters of crustaceans and eaters of worms, plant-eaters and honey-suckers, scavengers of carrion, and many a "picker up of unconsidered trifles."

Pride of place may be given to the hunters, and, as a type of them, to the Peregrine Falcon, described by the late Professor Alfred Newton as "the most powerful bird for its bulk that flies." It is a strong fierce bird with long pointed wings, spending no time on its comings and goings and dealing death in mid-air with relentless talons; in spite of game-preserving it still maintains its place as one of the most splendid of native British birds. Its prey consists mainly of other birds, and these it attacks in flight, "stooping" always from above, and killing, not by force of impact, but by the sheer grip of its claws. "Having arrived within a few feet of its prey," wrote Audubon of the almost identical Duck-Hawk of America, "the falcon is seen protruding his powerful legs and talons to their full stretch. His wings are for a moment almost closed; the next instant he grapples the prize, which, if too weighty to be carried off, he forces obliquely to the ground, sometimes a hundred yards from where it was seized, to kill it and devour it on the spot. Should this happen over a large extent of water, the falcon drops his prey and sets off in quest of another. On the contrary, should it not prove too heavy, the exulting bird carries it off to a sequestered and secure place." A peregrine can indeed carry a weight almost equal to its own, and a pair nesting on the Bass Rock, in the Firth of Forth, have been known to bring grouse and pheasants from the mainland across two or three miles of sea.

The Hunting of the Peregrine.

The Peregrine Falcon belongs to the aristocracy of the bird world. It has a haughty stare, a regal dignity, is absolutely fearless, has great reserve power, and, as Mr. Hudson says, possesses a courage commensurate with its strength and in hunting an infallible judgment. It is one of the most perfect of winged creatures, "so well-balanced in all its parts, so admirably adapted for speed, strength, and endurance." The lordly falcon is "the terror of the skies."

"Sooner or later the day always comes in early autumn to birdland when the peewits, feeding in silent battalions together, and the gulls, watching impatiently to rob the peewits of their worms, suddenly arise and wheel in wild disorder to the horizon; when the clustered partridge coveys crouch, like clods to the earth, and the flocks of small birds, feeding in the open fling themselves like a shower of stones into the nearest hedge; when the blackbird issuing from cover turns before he has flown a yard, and darts back again with a chatter of alarm; when,

Photo: Royal Scottish Museum.

GOLDEN EAGLE.

The largest of the British birds of prey. Soaring overhead, it is of majestic appearance. The young ones are taught how to hunt and how to kill as well as how to carry and skin their prey.

save for the distant cawing of rooks perched on lookout trees, a parish apart, sudden, perfect stillness holds the landscape. Then the peregrine falcon passes, smiting her way from horizon to horizon, and spreading terror as she goes. Who gave the first warning of her coming it is hard to tell. Possibly it was a rook. But the marvel is that the majority of the birds, being young ones of the year, can never have seen a falcon before; yet they fling themselves wildly to right and to left long before the speck

in the far skies reveals itself to human eyes as a bird of prey." [1]

The Golden Eagle is the largest of our native birds of prey. The well-known lines of Tennyson spring to the mind:

> He clasps the crag with crooked hands;
> Close to the sun in lonely lands,
> Ring'd with the azure world, he stands.
>
> The wrinkled sea beneath him crawls;
> He watches from his mountain walls,
> And like a thunderbolt he falls.

The Golden Eagle looks well after its young, feeding them at dawn and dusk each day. "The Grouse that are brought to the eaglet are plucked and headless; the Hares and Rabbits are skinned and made ready in a larder distant from the nest; the youngsters get only digestible food, being unable for some weeks to form pellets." The eaglets are taught how to hunt and how to kill, as well as how to carry and skin their prey. When they are about five months old they are driven away.

Photo: James's Press Agency.

RAVEN.
The brainiest of all our birds.

The Fishing of the Cormorant.

Very different from the habits of these birds of prey is the under-water hunting of the Cormorant, a bird of much less noble habits and aspect, which is notable for clumsiness in the air, and for uncouth appearance on land, as well as for the foul stenches of its untidy nest! Under the water, however, it is a thing of beauty, so perfectly adapted is it to the swift and dexterous pursuit of its active prey. In a tank with glass sides we may see this to great advantage, and note how the wings are kept close to the body—not used for swimming as in the case of penguins and auks—and how the air-bubbles cling to the feathers like bright jewels or polished silver. We can see, too, how the strong hooked beak is used to seize the fish, which is then borne to the surface to be tossed in the air, recaught, and swallowed, for the Cormorant does not swallow under water like a penguin. The Chinese train cormorants to catch fish for the market, a collar round the neck preventing the birds from swallowing their prizes; the same thing was done in Britain at one time, although only for sport.

Different Fishing Methods.

It is interesting to compare the different methods of fishing adopted by two of the Cormorant's relatives, the Gannet and the Pelican, and the different forms of beak which go with each. The Gannet, or so-called Solan "Goose," nests in great colonies on several of the rocky islets around the British coasts, and it may also be seen at most times off many parts which are far from these breeding stations. It is a bird of fine white plumage and noble flight, which, soaring at a height and then suddenly dropping like a plummet, uses its long straight beak to transfix fish swimming near the surface.

The Pelican, again, is a fisher of the shallows, which wades through the water with its enormous gape at full extent, and the great pouch below its beak ready to receive what comes. A party may work in concert, sweeping the pool in a long line like a living seine net. "The Cormorant pursues, twists, turns, and seizes; the Gannet soars, plunges, and spears; the Pelican sweeps and engulfs."

§ 6

The Wisdom of the Raven.

We may refer here to the Raven. Like some of the larger birds of prey, the Raven takes a wife for life, and they use the same nest year after year. As an inland bird the Raven is now not so frequently met with, for it has been driven by persecution from many of its former mountain haunts. Luckily it is one of the hardiest of

[1] E. K. Robinson, *The Country Day by Day.*

birds and can adapt itself to great extremes of temperature.

The Raven, the biggest of our Crows, is the brainiest of all our birds. "His family are the great legal fraternity among birds; nimbleness of wit mingled with audacity characterise them all, so that the very first time that I observed the hoodie crow at home I was struck with his laughable resemblance to a barrister in wig and gown. There was the same keen eye for the shortcomings of others, and the general look of mental superiority to ordinary folk."[1]

The Raven has the reputation of being one of the longest-lived birds; it enjoys a reputation also for mimicry. If you climb to its roosting-place on some mountain precipice you may hear "in the silence of the hills how the ravens croon themselves to sleep, uttering reminiscences of the sounds they have been listening to throughout the day." Mr. F. B. Kirkman, in *The British Bird Book*, writes: "From the growing congregation on the ridge there descended through the thickening dusk the strangest of evensongs—a weird, wild medley of many sounds: the barking of dogs, the bleating of goats, the lowing of cows, the becking of grouse calling across the moorland, and now and then the deep belling challenge of the stag." Their intelligence is almost uncanny, and when we think that they are of savage character and have a deep, harsh, human-like voice, we can imagine some explanation of the evil reputation of the bird, and the sombre superstitions associated with it.

§ 7

Social Life.

It has to be confessed that we have a great deal to learn about the inner life of birds. It is difficult to get mentally in touch with them; they have evolved on a different plane from our own. Our sense of kinship with animals is still something novel, but it is ever widening and deepening as we view it more closely and with clearer vision: may we not claim this as one of the steps in the progress of Evolution?

With birds, as with mammals, there are many phases of social life. Some species of birds are more social in their relationship than others; in some there is a more advanced state of community than in others. With individuals there may exist mutual friendship; companionship between two birds of the same species, or even between birds of different species, is often seen.

The helping instinct is characteristic in birds as in other animals; it is often touchingly human-like. We see it most often in parental care and in the feeding of each other by the sexes, but it is shown frequently in other ways. Mr. W. H. Hudson, speaking of the Military Starling of the pampas—a bird of social disposition—tells this story: "One day I was sitting on my horse watching a flock feeding and travelling in their leisurely manner, when I noticed a little distance behind the others a bird sitting motionless on the ground and two others keeping close to it, one on each side. These two had finished examining the ground and prodding at the roots of the grass at the spot, and were now anxious to go forward and rejoin the company, but were held back by the other one. On my going to them they all flew up and on, and I then saw that the one that had hung back had a broken leg. Perhaps it had not been long broken, and he had not yet accommodated himself to the changed conditions in which he had to get about on the ground and find his food. I followed and found that, again and again, after the entire scarlet-breasted army had moved on, the lame bird remained behind, his two impatient but faithful companions still keeping with him. They would not fly until he flew, and when on the wing still kept their places at his side, and on overtaking the flock all three would drop down together." As Mr. Hudson says, it is possible to mistake for friendship an action which, at all events in its origin, is of a different nature.

Instances of such altruistic behaviour, to be attributed to the *helping* instinct in animals of social habits, are common. Mr. Frank Finn relates that the upper bill of a Huia, an insectivorous bird of New Zealand, by some accident or natural deformity had grown into the shape of a corkscrew, and it was not apparent how it could get enough food to support life naturally. It seems it had been fed for some time by a devoted mate.

[1] Francis Heatherly, *The Falcon at the Eyrie*.

The Social Habit.

The development of a social habit at the breeding season is a well-marked characteristic of many kinds of birds, and it is by no means confined to those which are gregarious at other times; conversely, it is also true that some birds which at other seasons band together are among the least social at this special time. More than one factor is probably involved: the scarcity of suitable sites—for marsh-fowl, for example—may be a reason for concentration in special spots, and strength of defence against enemies may often be an advantage gained. In other cases the problem of food-supply will tend to produce distribution rather than concentration, and this is especially the case with many of the smaller species of our common birds: among warblers, for example, there is a marked tendency for a pair to select a small territory within which they will remain and from which they will endeavour to exclude all other members of their own species and even, in due course, their own young.

Photo: F. W. Bond.

SECRETARY BIRD.

The name is derived from the tuft of feathers looking like a quill stuck behind the ear. The bird lives in Africa and preys on small animals—notably snakes—which it kills with a swift stamp of one of its powerful legs.

Many birds, like human beings, would seem to enjoy the company of their kind. The gregarious habit is common, for example, among rooks, starlings, pigeons, swallows; parrots roam in bands, apparently for the pleasure of one another's company.

We may have crowds and associations, however, without sociability; a community of separate individuals may exist without there being any corporate life or power of acting as a unity. Still, we do see many instances of a capacity for unified action and distinct features of a social life. "There appears to be an intellectual advantage in sociability, if we may argue from the fact that many social animals show a high development of wits. The three cleverest kinds of birds are rooks, cranes, and parrots, and they are notably social. There is, of course, the danger of putting the cart before the horse, for it may be that the sociability is in part the expression of good brains. It may also be argued that the non-gregarious crow is just as clever as the social rook, and many analogous instances might be given."[1]

The Rook.

The Rook is the best example of our gregarious birds. There is no doubt that the members of the Crow family have fine brains, and great power of vocalisation which may develop to a remarkable extent. Experts tell us that the Rook has command of between thirty and forty notes. To learn to what extent they employ them one has only to listen to "the black republic in the elms," after the breeding season is over.

Professor J. Arthur Thomson, in *Secrets of Animal Life*, says: "Like many creatures well endowed with brains, rooks exhibit what must be called play. There are gambols and sham fights, frolics and wild chases, in which, curiously enough, jackdaws and lapwings sometimes become keenly interested. But who knows the real truth about rooks posting sentinels, which is so often alleged? Who knows the significance of the vast congregations that are sometimes seen, and who can tell us if there is any truth at all in the alleged 'trials' of individuals who have defied the conventions

[1] Professor J. Arthur Thomson, *The Wonder of Life*.

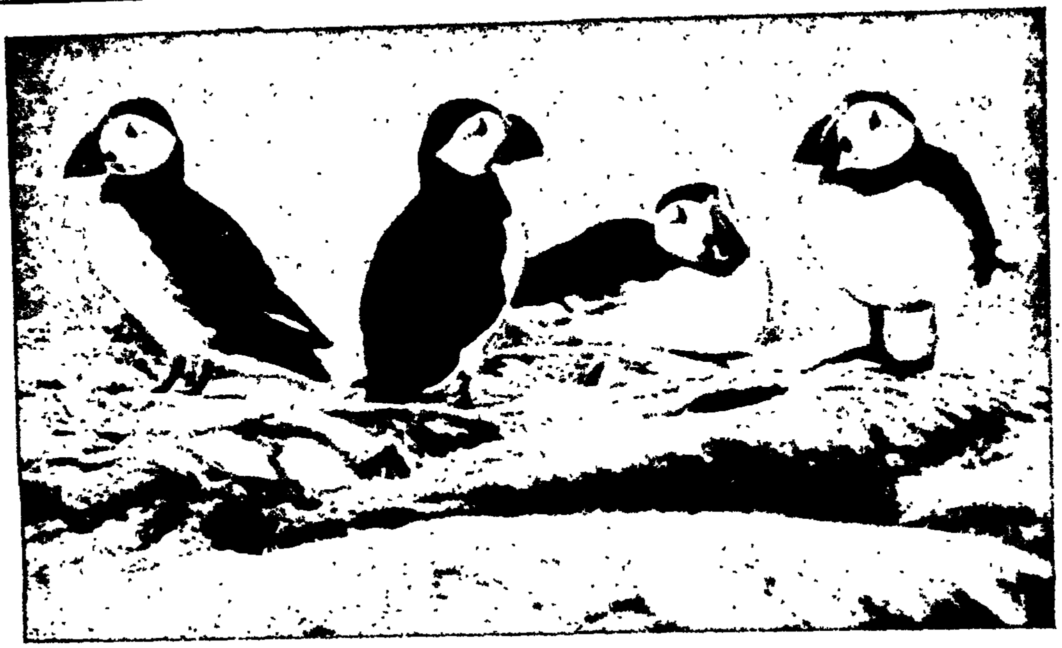


Photo: "Our Common Sea Birds" (Country Life, Ltd.).

PUFFINS.

The Puffin's beak is of singular appearance. After the breeding season its surface peels off in horny plates—shed like the deciduous bark of certain trees—a process parallel to the moulting of the plumage.

of the community? . . . But the central interest is in the rooks reaching forward to a communal life with certain conventions, and to the crowded nest in which we see the beginning of a continuous social heritage of objectively enregistered traditions." There may be far over a thousand nests in a rookery, and the same site may be used for more than a century.

Rooks certainly have a considerable vocabulary. There is not, indeed, any *language* in the strict sense—man has a monopoly of that; but the rooks have *words* just as dogs have, definite uttered sounds which have definite meanings. We hear the rooks use certain words when we move suddenly beneath the trees, and other words are uttered when a bird intrudes on its neighbour; there is a word when the rook sinks down upon the nest, and another word when it flies clear of the rookery and makes for the fields. What danger-signals, what scoldings, what chucklings, what exultation, what reproaches, what encouragement do we not hear?

Mr. W. P. Pycraft, in his *History of Birds*, says: "Among gregarious species some display a much more intimate association than others—are more social in their relationships. And this is shown very clearly in the devices which some species have adopted for their mutual protection during sleep.

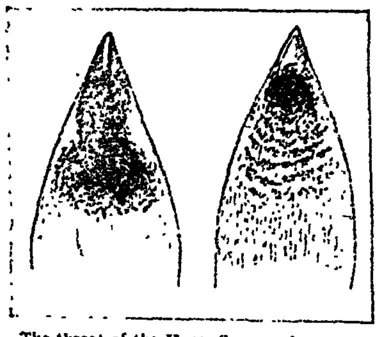
Mutual Protection.

The common partridge, as is well known, lives in small companies, or 'coveys,' which scatter only while feeding, and then not far enough to be beyond call. Later in the day, as soon 'as the beetles begin to buzz,' says Professor Newton, the whole move away together to some spot where they jug, as it is called—that is, squat and nestle close together for the night; and from the appearance of the mutings, or droppings, which are generally deposited in a circle of only a few inches in diameter, it would appear that the birds arrange themselves also in a circle, of which their tails form the centre, all the heads being outward—a disposition which instinct has suggested as the best for observing the approach of any of their numerous enemies, whatever may be the direction, and thus increase their security by enabling them to avoid a surprise. Ducks similarly take special precautions to secure safety during sleep, when this must be taken in exposed situations, as when, for example, they desire to doze between the intervals of feeding during the night, which they pass afloat. At such times they keep close together, and to avoid

drifting ashore keep one leg slowly paddling, and thus drive themselves round in circles."

There is sometimes co-operation in hunting, as we have already noted in the case of pelicans, which combine in a crescent and, wading shorewards, drive the fish before them; when they have got them cornered they fill their huge throat pouches. It is said that a pair of golden eagles will occasionally hunt in concert, one beating the bushes while the other flies overhead, waiting to pounce.

With birds, as with other animals, we see, as we do in human beings, that some individuals are gifted above others of their kind. A few may have a keener sense, greater strength or power of leadership, a more helpful spirit than their fellows. This counts for much in a social state. "The action of the gander and of the trumpeter in driving their fellows home in the evening must be regarded as similar in its origin to that of the male swift, when he hunts his mate back to the nest, and of the sand-martin I observed chasing the females of the colony to their burrows. In a lesser way it may be seen in any flock of birds; they move about in such an orderly manner, springing, as it appears to us, simultaneously into the air, going in a certain direction, settling here or there to feed, presently going to another distant feeding-ground or alighting to rest or sing on trees and bushes, as to produce the idea of a single mind. But the flock is not a machine; the minds are many; one bird gives the signal—the one who is a little better in his keener senses and quicker intelligence than his companions; his slightest sound, his least movement, is heard and seen and understood and is instantly and simultaneously acted upon."



The throat of the House-Sparrow has a very different appearance in summer (left-hand figure) than in winter (right-hand figure). This is due to abrasion; the light tips of the feathers are shed in spring, thus revealing the dark portions.

Inter-relations.

Many curious associations are formed by birds during the breeding season. The Puffin is quite capable of making a hole for itself in the face of some precipitous slope, but frequently it prefers to appropriate a rabbit's burrow, ejecting the rightful owner without ceremony. Other burrowing birds are often more accommodating, for the Burrowing Owls of America live amicably with the Prairie Dogs whose retreats they so often share, and in New Zealand the same holes are shared by Petrels and Tuatera Lizards without apparent friction. In cases of this kind, however, it is always possible that the partnership has other advantages—such as common defence or watchfulness—than the mere saving of labour on the one hand or on the other: there is the curious case, for instance, of the Ruddy Kingfisher of Borneo, which makes its nest in the hive of a peculiarly vicious kind of bee!

§ 8

Our Common Birds.

The late Professor Newton has an interesting passage in which he shows that we can tell which birds were most familiar to our forefathers by their having a pet name added. Thus the Daw is the Jack Daw, the Redbreast is Robin, the Wren is Jenny, the Pie is Magpie, the "Mag" being short for Margaret. In early prints of ploughing, the closeness of the connection between men and birds is naïvely pictured. In one of the earliest illustrations of sowing, for instance, the birds crowd so closely on the heel of the sower that they have to be driven off with stones or even whips, and they are seen springing beyond the leap of the small dog that has been sent to chase them. In modern times the charm possessed by birds is partly that of friendship, but more that of delight in their songs and feathers. The following birds form only a few examples chosen for some special interest.

The Nightingale.

It has often been disputed whether the Nightingale's song is really the sweetest. It certainly owes something to the stage on which it is set, for when the bird arrives the field and garden are gay with spring flowers. The Cuckoo arrives just about the same time. It sings all day, but the Nightingale mostly in the evening, and the sweetness of his note is enhanced by the light of

Photo: J. H. Symonds.
HEN NIGHTINGALE.
The mate of our most famous songster.

stars and the scent of blossom. Whether it is a melancholy or a merry song has long been disputed. It certainly is not loud, because when the Nightingale sings by day it is not noticed amid the clamour of other bird music. Mr. W. H. Hudson says: "Its phrasing is more perfect than that of any other British melodist, and the voice has a combined strength, purity and brilliance, probably without a parallel."

The Blackbird's voice is remarkable for its great strength and for the wonderfully rich quality of its tone. He is a clever mimic, like several other songsters, and has been heard to imitate the Nightingale's song with some measure of success. There are several recorded instances, too, of his crowing exactly like a domestic cock—"apparently enjoying the sound of the responses made by the fowls of the neighbouring farmyard"—and of his cackling like an egg-proud hen! Some prefer the song of the Blackbird to that of the Thrush. It certainly is the sweeter of the two, but it is not so long continued. It may vary with the district, and some hold that the Surrey Blackbird is the sweetest songster of his kind. The period of song is identical with the visit of the most delicately beautiful of all butterflies—the Orange-Tipped. Even the little Song-Thrush, a close relative of the Blackbird, is a louder and more persistent singer than the latter, although in that respect he does not compete with the larger Missel-Thrush, which can often be heard pouring out his bold loud notes from the topmost twig of a bare tree in the month of January. The song is in keeping with his character. Mr. W. H. Hudson thinks that "The Throstle is by far the finest songster. His chief merit is his infinite variety. His louder notes may be heard half a mile away on a still summer morning, his

The Blackbird and the Song-Thrush.

Photo: Oliver G. Pike (in "Country Life").
WHINCHATS.
From its perch on the top of the hedges or on low trees, or whilst hovering in the air, may be heard the Whinchat's curious short whistle, *tu-tick-tick*, the latter two notes being exactly like the sound made by hitting two small pebbles together.

lowest sounds are scarcely audible at a distance of twenty yards. His purest sounds, which are very pure and bright, when contrasted with various squealing and squeaking noises, seem not to come from the same bird. . . . As a rule, when he has produced a beautiful note he will repeat it twice or thrice." While the Blackbird is cunning and secret in his ways, creeping round the roots of the yews and other shrubs, the Thrush boldly roams across the fields.

The Lark.

The songster most closely associated with the farmlands is undoubtedly the Lark. He is the earliest rising of all the birds, and when in full voice, as he is just about the time when the young wheat is tall enough to cover him, he may be heard pouring out his song before sunrise. He is not one to confine his charms to his courting days, but has been heard in every month of the year except September, his moulting time. It is in Spring and early Summer, however, that he pours forth his best music. The song has words for it in the folklore of many counties, and the following rhyme succeeds in conveying an idea of it:

> Tu whit, tu whit, tu whee,
> No shoemaker can make boots for me.
> Why so? why so? why so?
> Because my heel's as long as my toe, my toe.

No voice is more closely associated with the beautiful wooded landscapes of England than the love-song of the Wood-Pigeon. According to an ancient legend, the words it tries to say are "Tak two coos, Paddy," the legend being that in the Golden Age the Wood-Pigeon laid its eggs on the grass, but they were trampled upon by two cows. An Irishman led one away, and the Wood-Pigeon prays in vain for him to take the other, to which the Partridge is supposed to reply "De'il tak it"—a wonderfully close imitation of its apology for a song. The Little Dove, the Turtle Dove, or the Croodling Dove has a sweet short song that fits in well with the whisper of the summer leaves. It is an old country saying that when you first hear the croodling of the Little Dove, then is the time to sow your swedes.

The Wood-Pigeon.

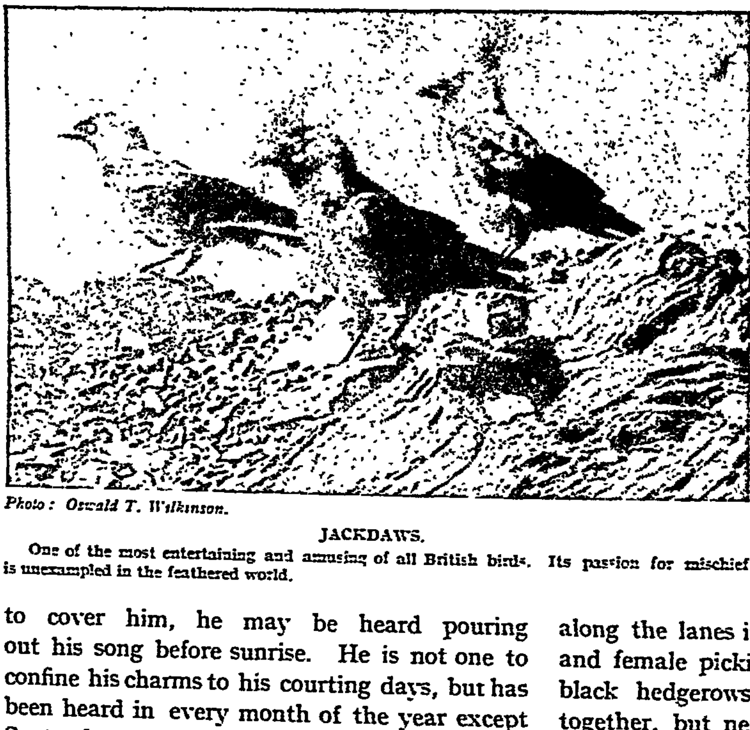


Photo: Oswald T. Wilkinson.

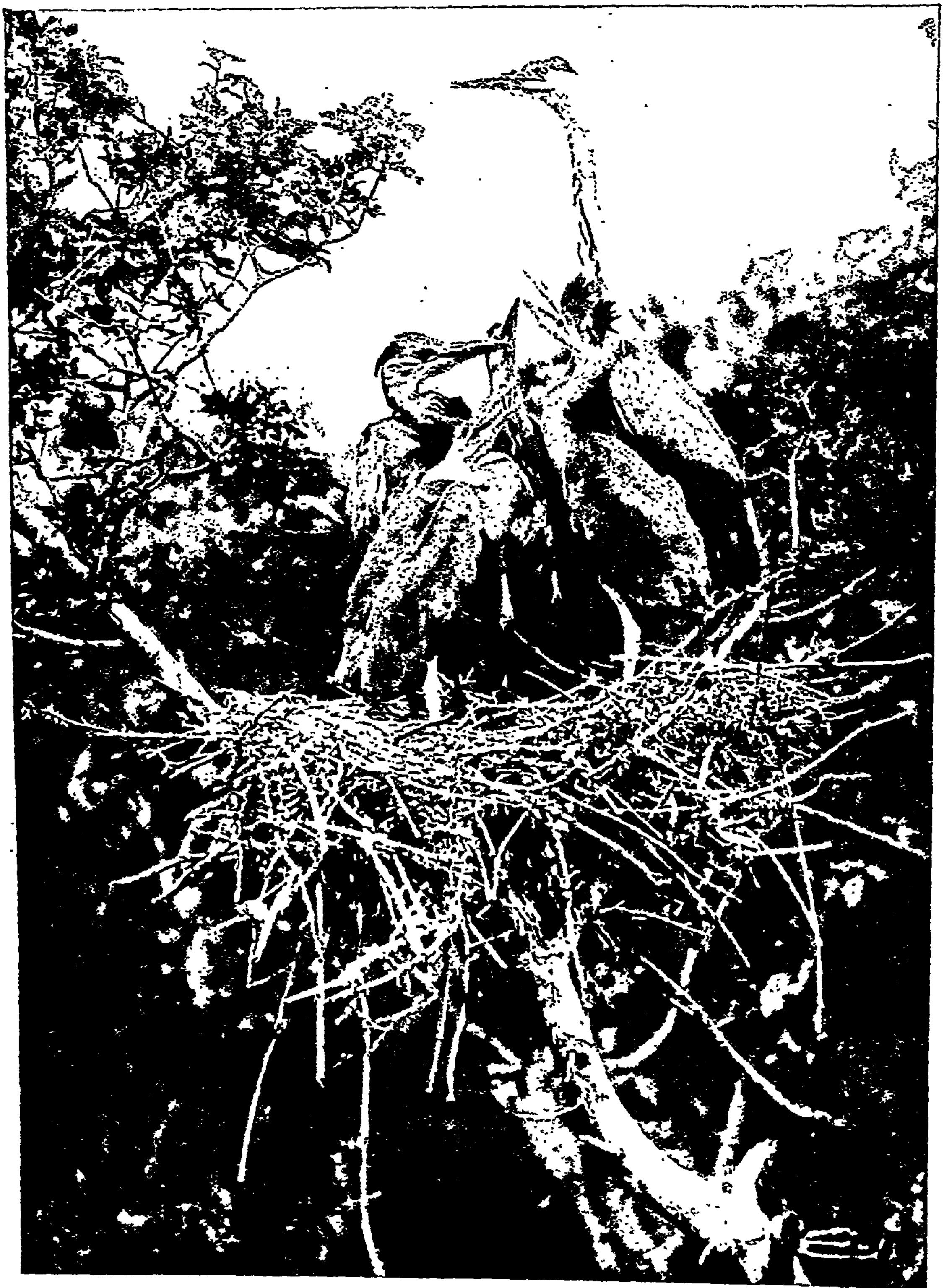
JACKDAWS.

One of the most entertaining and amusing of all British birds. Its passion for mischief is unexampled in the feathered world.

The Bullfinch and the Goldfinch.

One has often wondered if there is a manner of accounting for the different marital qualities that characterise birds. Take the cock Partridge, and you find a model father—one that will stand up to anything in defence of his young—while the cock Pheasant is a very gay Lothario. The most faithful of our birds is the Bullfinch. The male and female do not only stick together during the breeding season, as is the case with most birds, but along the lanes in winter you may see the male and female picking up morsels of food on the black hedgerows. They do not keep close together, but never go out of hearing of one another, and it is very easy to imagine words for the conversation which they keep up. The Goldfinch is perhaps the most beautiful of all the feathered folk in the English landscape. In Autumn it is a very pretty sight to see a little cluster of them feeding on thistledown, and performing the most delicate acrobatic feats in balancing themselves so as to pick it from the plant.

Variety of character in birds is nowhere more marked than among the more familiar inhabitants of the woodland. Take the Jay—clean-



From "Wild Life in the Tree Tops."

HERON (WITH YOUNG).

The Heron, rising in the air and fleeing from its enemies, the Falcons, "will, in its efforts to lighten itself, and so keep *above* its pursuers, disgorge any food which may still be undigested. So that in watching such a flight one might expect to see a small shower of—for instance—fish and shrimps fall from the clouds."

A Few Woodlanders.

made, bright-coloured, with a voice that is raucous but seems always in tune with the noise which the wind makes blowing through the tall trees. He is a gentleman in appearance, but his flight is as awkward as the gait of a yokel. Moreover, Nature has endowed him with a thieving and lawless character. He steals the eggs from the nest, and makes a meal of any fledglings that he can lay hold of. Yet he is very cunning about concealing himself during the breeding season, when he has to think of the safety of the family as well as his own. For the time being, the loud cry is stilled, and the bird, on being disturbed, shifts slyly and quietly from one tree to another. He has a natural genius for concealing his nest, and in that way differs very much from his relative, the Magpie, whose idea of architecture is simply to pile woody twigs upon woody twigs, so as to make a conspicuous and monstrous habitation. The Magpie used to be a favourite domestic pet, but its numbers have now been greatly reduced, so that to see several of them together, which used to be considered very unlucky, is almost impossible in some districts. They very often go in threes, for some reason which we cannot explain. The Magpie can be taught to articulate a few words; he is inquisitive and loquacious. "The usual sound emitted by the magpie is an excited chatter—a note with a hard percussive sound rapidly repeated half-a-dozen times. It may be compared with the sound of a wooden rattle or to the bleating of a goat, but there is always a certain resemblance to

Photo: James's Press Agency.
MAGPIE.

the human voice in it, especially when the birds are unalarmed, and converse with each other in subdued tones." The Heron is a bird of the woodland, in so far as it is there he makes his heronry. It will frequently be found closely adjacent to a rookery, but the two colonies do not always live at peace, although in a case the writer knows of, quite near London, they have done so for many decades. The Rooks are numerous and aggressive; and though an individual Rook could not hold its own with a Heron, numbers usually prevail when a battle royal takes place. In habit the Heron is a bird of the brook and river, and there can be little doubt about his favourite diet being of fish. He loves to stand in a clear, shallow stream, apparently motionless, but should an eel creep out, or a bolder trout try to make a passage upstream, the Heron's keen eye sees it at once and down comes his beak like a sharp spear, the chances being that the next experience of the fish is that of being borne through the air, to be eventually swallowed and either wholly or partly digested. In the latter case, the process is stopped in order that the young may receive the food in a softened condition.

MEADOW PIPIT CLEANING ITS NEST.
It picks up the excrement of the young, which is enclosed within a gelatinous capsule, and carries it off to a distance.

The Green Woodpecker is a common British species, whose bright plumage is less conspicuous among the trees than might be thought, but whose presence is often betrayed by the loud cry—like a burst of demoniac laughter—or by the strong "tap, tap, tap" of its beak as it sounds the tree-trunks for rotten portions where insects may be found. The woodpecker's strong beak, adapted to its mode of feeding, is

Photo: Royal Scottish Museum.

COMMON GULL (*LARUS CANUS*) WITH NEST, EGG, AND YOUNG.

Colonies of them are often found on lochs at a distance from the sea. The birds roam over moors and marshland, and they are often to be seen closely following the plough, picking up worms and grubs. Like the Herring-Gull, it has been observed dancing on the sand or mud of shallow pools to force up marine worms from below.

well suited also for the work of excavating a nesting hole, and a deep cavity with a small horizontal opening at the top is hollowed out.

The Waterhen and the Coot.

The Waterhen looks black at a distance, but on closer observation discloses many charming shades of colour. It is a bird that seems to thrive and increase in numbers more than its companion, the Coot. Yet it nests often in a perilous position. You may seek for the nest either among the rushes and flags at the border of a stream or on the long willow branches that stretch out close to the surface of the water, if they are not touching it. Country folk believe that in every normal year there is a May flood, and when that comes the water very frequently lifts the nest of the Waterhen out of its mooring and carries it down-stream. The faithful bird will go a long distance in its curious little ship, but is compelled to vacate it at last, as such floods carry down the branches of trees, trunks that have been lying on the bank, and a great deal of miscellaneous debris capable of wrecking the poor craft. Not that the Waterhen is likely to suffer personal injury, as she will dive into the strongest running stream and escape scatheless.

The Grebes.

The Little Grebe is to be met with on inland waters all the year round. In winter it resorts to rivers and larger bodies of water, when the small ponds beside which it often nests are apt to be frozen over. Its supreme accomplishment is that of diving and hiding itself among the stems of water-plants or other cover. It must, of course, come up, but it is amusing to notice the length of time it will remain under the water, and the distance it will often travel before it makes a second appearance. The Great Crested Grebe is one of the stateliest and most beautiful of our inland water birds.

Visitors from the Sea.

One of the most beautiful sights to be seen in this country is that of a colony of Black-headed Gulls nesting beside a lake or in swampy places far away from the sea-coast and estuaries where they may be found in winter searching for small fishes or other food cast up by the tide. In days of old their eggs were prized as food, and even the young were taken, but the modern palate does not set so much value on them. The movements inland are made with great regularity, the birds appearing at one gull-pond, of which we know, about March 27, scarcely ever a day before or a day later. They raise their young while the Corncrake is singing its mournful and monotonous ditty in the new grass and the growing wheat. A hill country attracts them because of the little streamlets which provide plenty of food. They know as well as the angler does that the trout lie

with their heads up-stream, waiting for any little titbit in the shape of a worm or fly which the water brings down. When the Gulls are fishing, one can watch them beating their way up past a succession of gravelly shells into which they occasionally dip for a prey. When they come to the end of the beat, they fly back round the shoulder of the hill out of sight of the stream and resume operations where they started before.

There is no prettier adjunct to a moorland, or a bare field, than a flock of Lapwings. They fly together and alight together in Autumn and Winter when not breeding, but in nesting-time they go in pairs, though usually there are dozens and sometimes hundreds in the same field. The bird is a simple creature in so far that its nest is little more than a slight hollow on the bare earth. In Spring they can be seen sitting on their eggs without making the slightest attempt at concealment, so that the individual who goes out to collect their eggs need only march up to a sitting bird, but if it rises he must keep his eye on the place from which it springs. There never can be much doubt as to whether or not the nest is close, because, if it is, the birds shriek and swoop at the intruder, as if they were going for his head or eyes. Should an animal other than a man come, they will indeed carry out the threat. No sooner are the young out of their shells than they begin to run, and if chased, will select a hiding-place. It may be close by stones as grey as themselves, or in the short herbage which early Spring brings with it. A trained eye is needed to distinguish them from their surroundings, even at a short distance.

Birds of the Moorland.

The Curlew haunts the sea-shore during the greater part of the year, but in Spring retires to some slack or valley in hilly country, and makes a nest on the ground. The situation is generally very lonely, and the watchful birds quickly show themselves alive to the presence of a stranger. Usually, their note is a monotonous and melancholy sound, heard, as it often is, at night-time in the stillness of the moorland, but we know of no other bird that makes the clamour the Curlew does when its domestic privacy is invaded. It flies up and down the valley, shrieking to awaken the echoes, and looking as if it would like to do something dreadful to the human who had ventured into its domain.

LAPWING OR PEEWIT, SETTLING DOWN ON ITS EGGS.

If an intruder comes near, the young will take warning from their excited parents wheeling overhead calling "pee-a-weet, pee-a-weet" and squat flat on the ground in absolute stillness. No noise will make them move a muscle so long as their parents call overhead.

The Snipe is the most difficult of indigenous game-birds to shoot, on account of its trick of half-stopping and suddenly darting. During the breeding season he performs curious antics in the air, rising to a great height, and "precipitating himself downwards with astonishing violence,

producing in his descent the peculiar sound variously described as drumming, bleating, scythe-whetting, and neighing." The peculiar drumming sound was long the subject of controversy, but recent observations have made it clear that it is due to the vibration of the two outer tail-feathers, which have a peculiar structure.

§ 9

The Cuckoo.

The Cuckoo, as is well known, not only builds no nest of its own, but foists its eggs on other species, and has its young reared without trouble to itself but to the great detriment of the rightful children of the foster-parents. The story, indeed, is one of the most curious in the whole realm of natural history, and the facts are now becoming better known; among other new evidence, the recent intensive observations and wonderful cinematograph records of Mr. Edgar Chance have placed several points beyond doubt.

The Cuckoo's Procedure.

It seems to be the case that each female cuckoo has its chosen territory of operations and that deliberate choice of nests is made in advance of the date of laying. When the time for laying comes, the selected nest is approached, the cuckoo takes an egg from the nest in its beak, settles on the nest, lays its own egg, and then flies away with the stolen egg, which it either eats or drops at a distance. The whole manœuvre takes but a few seconds and may be carried out despite the frantic efforts of the small and unwilling hosts to drive off the intruder. Sometimes the procedure varies, for no cuckoo could lay in a wren's domed nest, for instance, and in cases of that kind the egg must be laid outside and inserted with the beak. The point of principle, however, is that the cuckoo certainly does not fly about carrying an already laid egg and looking for a suitable nest to victimise.

The Young Cuckoo's Part.

One cuckoo does not normally lay two eggs in the same nest, but different cuckoos may chance to select the same victim if there has been encroachment of territory. Once the act has been accomplished the foster-parents do the rest until the eggs hatch out; then begins the second part of the Cuckoo's villainy, for the young foundling has in his earliest and comparatively helpless days the inborn habit of removing the other chicks from the nest by getting his back under them and heaving them overboard. So it happens that the foster-parents are soon left with but one charge, whose voracity keeps them perpetually busy and whose body speedily fills up the nest. Still the poor dupes go on feeding the parasite, even when he is much bigger than they are; one of Mr. Chance's photographs shows a bloated young cuckoo sitting on a post, while the much smaller pipit dutifully feeding him must needs stand on his shoulder, so to speak, for the purpose! The whole story is one of effective adaptation on the part of the Cuckoo and of the weakness of blind instinct on the part of the foster-parent.

The most interesting theoretical point about the Cuckoo has to do with the colour of the eggs, which is very variable, but tends to be like that of the eggs of the chosen foster-mother. That one hen cuckoo always lays the same type of egg seems to be thoroughly established, but it is still a matter of speculation whether the character is hereditary and, if so, in what manner.

The Cuckoo victimises a large number of different species as foster-parents for its young, but all the usual ones are small insectivorous birds. The degree to which the Cuckoo's egg resembles the others varies greatly; sometimes there is almost a perfect match, at least in colour, but in other cases the similarity is slight or even non-existent.

§ 10

MIGRATION

The scientific investigation of migration is greatly complicated by the difficulties of making observations. It is not now believed that the greater part of migration takes place at immense altitudes, and at an accelerated rate of flight which makes enormous journeys possible for birds in a single night. Nevertheless it remains true that a great deal of migration is nocturnal, and that, for other reasons also, it is difficult to observe. At certain times and places, however, much migratory flight can be actually observed. We have, for example, this recent description of the passage of swallows on Heligoland: "All

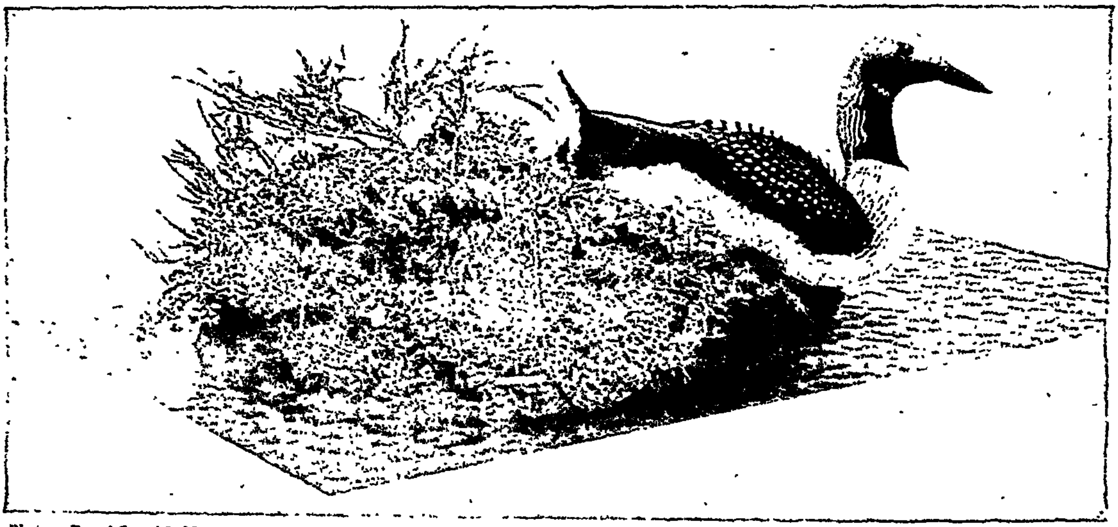


Photo: Royal Scottish Museum.

BLACK-THROATED DIVER (*COLYMBUS ARCTICUS*) WITH NEST AND EGGS.

A beautiful bird which nests in some remote parts of Scotland, but is commoner as a winter visitor to our coasts. The nest is usually close to the water on an island in some small loch. The bird's legs are set very far back for purposes of swimming and diving; on land, therefore, it does not stand upright, but pushes itself forward on its breast.

conformity to immediate conditions. For an explanation of this ancient origin of the instinct we should doubtless look to the former history of birds for some more compelling circumstance capable of initiating the habit which is still maintained. Some have supposed that the last Glacial Epoch, or Great Ice Age, may have driven birds gradually southwards, and after a long time allowed them to return gradually northwards: but during the second phase, *it is thought*, they would come north only for the summer and return in between to the alternative home they had learnt to know. Others have imagined birds as originating in the south and gradually extending their range in search of fresh feeding-grounds for the hungry mouths of the breeding season, going further and further each summer, but always returning in winter to the original cradle of the race.

If we admit that the immediate seasonal changes are insufficient in themselves to cause migration, beginning so early in each autumn as it does, we must yet invoke them *to some extent* to complete the other theory. If migration is an ancient habit, annually reborn, there must still be some immediate factor stimulating the latent instinct. Events not in themselves of sufficient strength as causes may yet serve to release more powerful energies, just as a detonator explodes the bursting-charge: so may subtle changes, either in the seasons or perhaps in the functional cycle of the bird's life, awaken the compelling instinct which causes birds to cross unknown seas and continents in accordance with some ancient plan.

How do Migrants Find their Way?

What routes do migrants follow, and how do the birds find their way? We must remember here, again, that migration is in the main a very orderly phenomenon which takes place year after year according to the same pattern. We have now evidence, too, that as regards summer quarters, at least, it is common for birds to return to the same places with great accuracy. Any suggestion, therefore, of a mere haphazard movement with a vague general direction may be dismissed as being inconsistent with the facts as we know them. Other points to be remembered are that much migration takes place at night, and that wide stretches of open sea are habitually crossed. Furthermore, the young of the year in many species migrate southwards before the parents—in the case of the Cuckoo, long after their parents—and must thus find their way without any memories to guide them. Anything which lies in the experience of the race, as distinct from that of the individual, must in these cases be handed on by inheritance purely and not by tuition and imitation.

Our knowledge of the routes that birds follow in their migratory flights is still very scanty. Hooded Crows caught and marked as birds of passage at the south-eastern corner of the Baltic have been shown to come from Southern Finland and the Petrograd district of Russia, and to follow the coasts southwards and westwards as far as the north-eastern corner of France. Black-headed Gulls ringed at the same place, but as nestlings, have been reported from right round the coasts to the Bay of Biscay, from along the courses of the Rhine and the Rhone, and as far as the Balearic Isles, and from along the courses of the Vistula and the Danube and across to Northern Africa.

In its migratory flight the whole life of a bird is raised to a higher pitch. It is estimated that many birds attain a speed of fifty miles an hour, and a carrier-pigeon has been known to keep up the rate of fifty-five miles an hour for four successive hours. It is unlikely that this is often surpassed by migratory birds on long-distance flights.

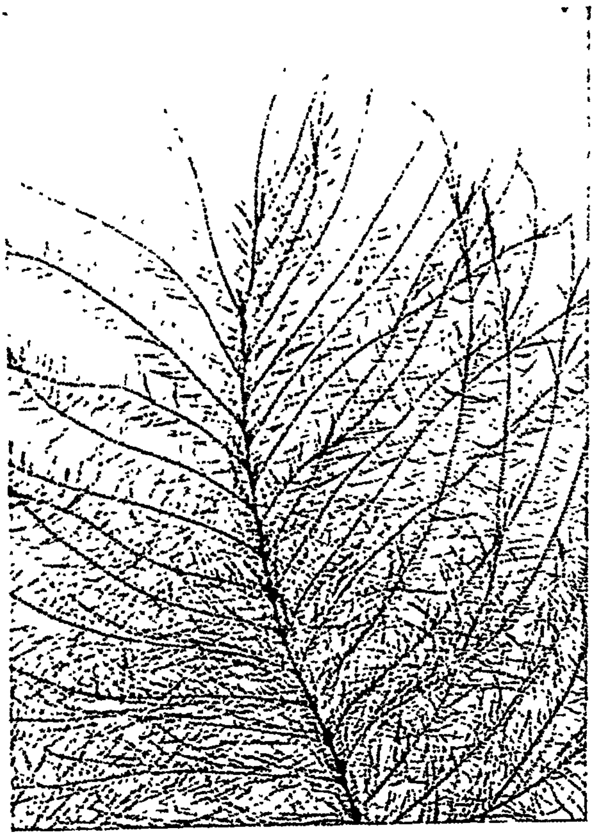


Photo: F. R. Hinkins & Son.

Portion of tip of downy feather from the under tail-coverts of the Missel-Thrush. (Highly magnified.)

"Homing."

The question "How do birds find their way?" is not one which can be answered at present. More must first be learnt of the nature of the routes which are in fact followed by migrants, of the relationship of particular summer quarters to particular winter quarters, and as to whether winter quarters are as clearly defined and as accurately sought out as summer quarters are known to be. It is probable, however, that the question may be narrowed down by the elucidation of that special acuity of the senses, or whatever it may be, which underlies the "homing" capacity so well known in birds. Recent experiments by Professor J. B. Watson and Dr. K. S. Lashley have had as their subjects the Noddy and Sooty Terns nesting on the Tortugas Islands in the Gulf of Mexico. Birds taken from their nests and transported by ship in closed cages were shown to be capable of finding their way back from Galveston (to the east) or from Cape Hatteras (to the north), distances of over 850 miles, or from intermediate points at sea entirely out of sight of landmarks of any kind. In being taken northwards, too, the birds were removed beyond the limits of the species' natural range, and the absence of any previous experience in that direction was all the more certain. At least, therefore, we must concede a very highly developed "sense of direction" or "bump of locality."

§ 12

PLUMAGE, COURTSHIP, AND MATING

It does not come within the scope of this work to go into the question of the general classification of birds, neither can we consider in detail the characters of bird structure or of feathers and plumage. A bibliography is given at the end of this chapter which will be useful for readers who wish to have more information on these interesting subjects. A volume might be written on any one of them. We cannot pass over altogether, however, the nature of feathers and plumage.

The acquisition of feathers must have been one of the great steps in the progress of birds

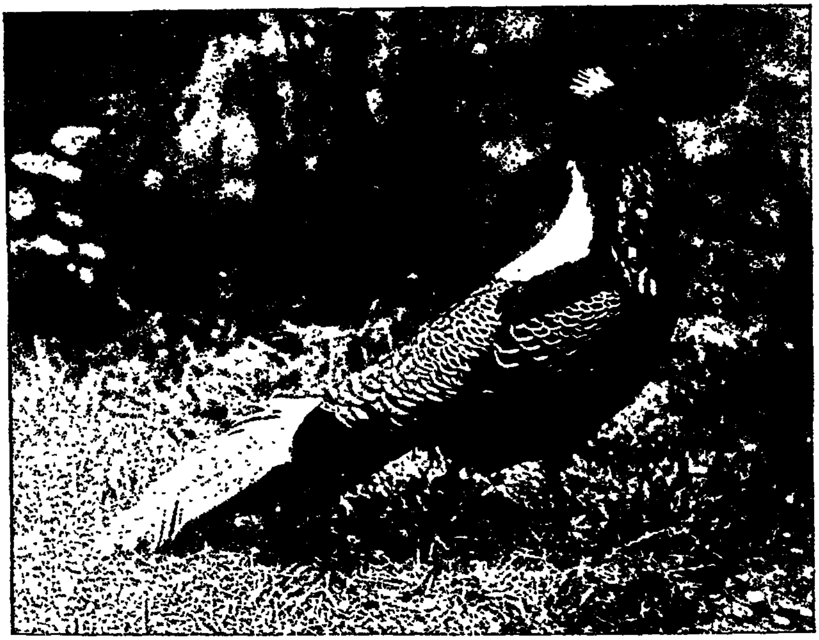


Photo: James's Press Agency.

SWINHOE'S PHEASANT (MALE).

Another example of brilliant plumage lending itself to "display" during courtship.

towards their present position as the supreme flying animals *par excellence*. It is indeed but to forge another link in that evolutionary history to find that feathers are modified scales and therefore closely akin to the typical covering of reptiles. Let us notice, too, that the unfeathered parts of a bird bear ordinary scales, the one form, as it were, simply replacing the other where it is more suitable. The scales on the toes are often suggestively reptilian in appearance, and when there are also feathers about the toes they grow not *on* the scales but from *between* the scales—from between the other scales we may indeed say to emphasise the point.

Plumage Coloration.

The feathers of many birds are richly coloured, and even those of sober hue may be very beautifully marked. In some cases the colours may be due to actual pigment; but in others, especially blues and greens, the minute physical structure of the feathers is responsible and wonderful effects of iridescence are produced.

Brilliance of plumage is often associated with the mating season, but this is far from being a general rule. In some instances the male has a special breeding plumage, and sometimes both sexes have this, examples of each kind being found among the Plovers. In other cases the male has brilliant plumage for most of the year, like the Mallard, while his mate is always dull. In many species, on the other hand, the sexes are alike and have a similar appearance all the year round; this permanent plumage may be dull-coloured as in the Song-Thrush or Curlew—wonderfully beautiful birds, nevertheless—or brilliant as in the Kingfisher. Most birds that have a permanent bright plumage, however, are dull in their first year, as is the case with the afterwards splendidly iridescent Starling, but in some cases, such as the Kingfishers and the Parrots, the gorgeous plumes have appeared before the birds leave the nest. One other kind of change must also be mentioned, namely, the seasonal changes of the Ptarmigan, which is white during the season of snow and of duller appearance when its native hills are brown once more.

Courtship and Mating.

Some of the most interesting habits of birds are those associated with the mating season. In many cases there are curious ceremonies of courtship, often with wonderful "display" of brilliant plumage or with great exuberance of song, and sometimes there are fierce fights between rival males. The Peacock spreads and erects his

magnificent train, the Argus Pheasant displays long plumes on his wings as well as on his tail, and the different Birds of Paradise glow with gorgeousness in their almost every feather. Many a relatively "dowdy" bird—as judged by human eyes—may also be seen posturing in much the same way as his more ornamental brethren, and we must be chary of denying to any bird strange beauty in the sight of his love!

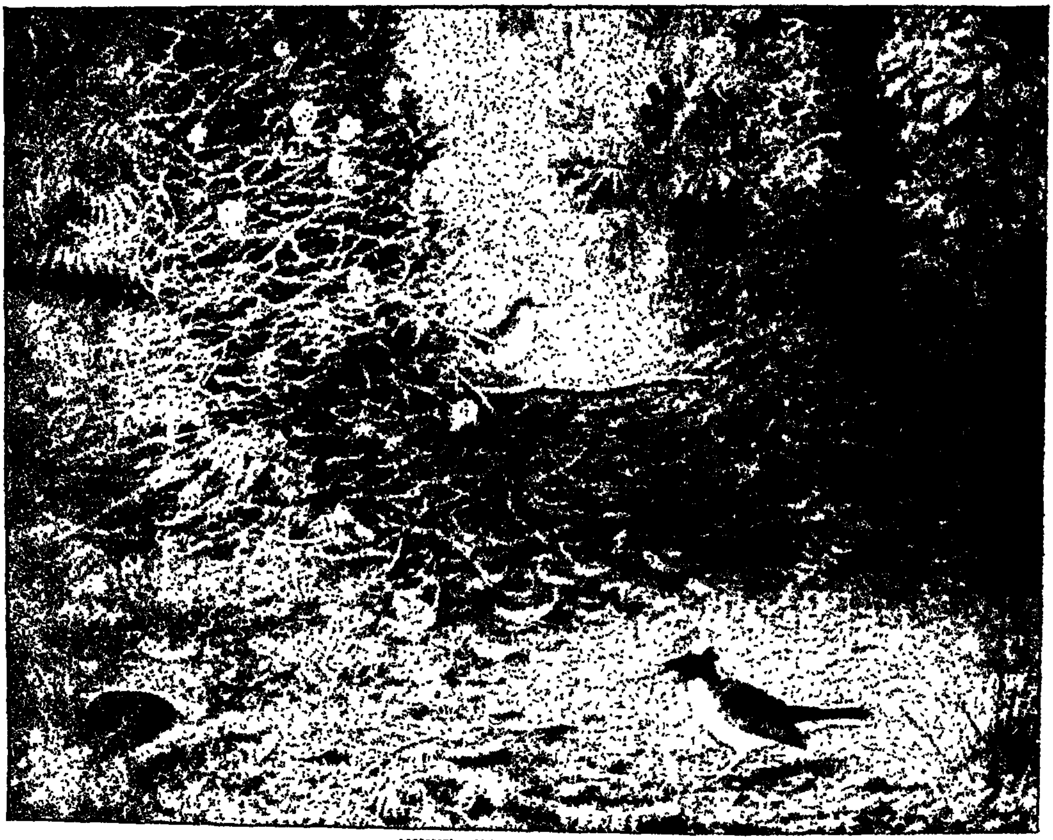
In the ordinary Black Grouse we may find a habit of display as well marked as that of any inhabitant of tropical jungles; it gives, indeed, an example not only of individual display but also of a collective "tournament" in which rival blackcocks strive to impress the greyhens which they wish to win as mates. In Scotland, say, the fortunate may perhaps witness a gathering of blackcocks at break of day early in the breeding season. The birds assemble in some open spot and indulge in the wild whirring calls that form their song of love and war, and the racket may be heard two miles off.

Then the tournament begins. It may be mere skirmishing, a display of fencing, or "sparring," or, as sometimes happens, these harmless encounters may develop into fierce fights and sometimes a duel to the death.

"At intervals during each separate fight, blackcocks emit a curious call; it is almost a hoarse screech, resembling the noise too painfully familiar to us, namely, that of cats on housetops supplemented by the said animals being afflicted with sore throats. The sound is both wild and unmusical in the extreme.

"We will suppose that the observer has come early on the scene, before the greyhens have made their appearance. The approach of one of the latter is the signal for an immediate cessation of hostilities on all sides, and intense excitement prevails amongst the assembled blackcocks. Her approach has been observed by a single bird, who has been sharper than the rest in detecting the lady afar off . . . he will suddenly draw himself up to a rigid position of attention, till he is sure she is really coming. Having settled this in his mind to his own satisfaction, he throws himself into the air and flutters up a few feet, uttering the while hoarse notes with all the power and effect he can muster.

Reproduced by permission from "Game Birds and Shooting Sketches," by J. G. Millais.
BLACK-COCK ON THEIR PLAYING-GROUND.



NEWTON'S BOWER-BIRD.

There are several species of Bower-bird, all displaying remarkable habits in their courtship. In the case of the Gardener Bower-bird the nest itself is in the tree; at the foot of the tree a kind of cabin is built. "In front of it is arranged a bed of verdant moss, bedecked with blossoms and berries of the brightest colour"—regularly renewed as they wither. "The use of the hut, it appears, is solely to serve the purpose of a playing ground or as a place wherein to pay court to the female, since it is built long before the nest is begun."

"This is, of course, done to impress the lady in his favour, and arouse in her breast a proper sense of admiration, which he considers his due. His example is immediately followed by all the others, who, on alighting, dance about in the most absurd manner, each one trying to see who can screech the loudest and be the most ridiculous in his antics.

"When a hen has alighted on the playing ground the male that is nearest to her pairs with her, and fights off any other that disputes his possession. She then meanwhile walks sedately round her lord and master, picking about the grass coquettishly, and pretending to be feeding. Each hen on arrival causes the same general excitement and is appropriated by one or other of the successful cocks till the harems are filled up, one cock having at times as many as six or seven hens. As the season advances, after the first few mornings of the hens coming to the ground, they resort to the same spot each day and stay with the same cock who has previously trodden them, and are not interfered with afterwards by other cocks, who acknowledge the superior claims of the male to whom they rightfully belong."[1]

In some cases there are special aids to display, such as the pouch in the neck of the Great Bustard, which the cock can distend at will and use as an aid in the erection of his feathers; Pigeons, too, have a similar habit of inflating their "crops," although they lack special plumes; and the Frigate-bird has an external pouch which itself serves as an ornament, being of naked skin, bright red in colour, and very extensible.

[1] J. G. Millais.

From a photograph *by J. F. Russell, Dingwall.*

STAGS FIGHTING WITH THEIR FORE-FEET.

The Red Deer stags grow and shed their antlers annually. During the period of growth the horny substance is traversed by nerves and blood-vessels and is covered by a soft, sensitive sheath of "velvet." When the antlers are fully developed they become hard, non-living structures and the "velvet" dies and is rubbed off. A few months later the whole antler is shed and the process begins anew. The fiercest combats are in the mating season, and then the antlers are used, but when the new horn is still "green"—and again when the old antlers are being shed—fighting is with the fore-feet in the manner shown. (See *Natural History : II. Mammals*, page 331.)

Examples could be multiplied almost indefinitely; but we must here confine ourselves to one other case which has a novel feature of its own. The different species of Bower-birds found in Australasia build various types of "bowers" which serve as playgrounds in which the cocks court their mates. These "bowers" are often large and complex structures of twigs or flower-stems and are decorated with collections of blossoms, shells, or brightly coloured berries. One species builds a little cabin, some two feet high and three feet in diameter, at the foot of a tree and with a wide mossy "lawn" in front, while another makes a tunnel several feet long and completely roofed over with twigs. These bowers form the birds' courting grounds and are quite distinct from the nests, which are built in trees at a later stage.

The Bower-birds of Australasia.

Fighting with rivals plays a part of varying magnitude in the loves of different birds. Some species are well known for their pugnacity, the familiar Robin for instance; and in cock-fighting this has been turned to account as a source of human entertainment. In the domestic cock and in pheasants the development of spurs as weapons of offence is well known, and in some kinds of birds there are several pairs. Other birds fight with their wings, and lapwings may be seen buffeting each other in mid-air; an Egyptian relative of the Lapwing, the Spur-winged Plover, has a weapon on its wings which is said to make a fatal result no uncommon occurrence. The Ruff, a kind of sandpiper now numbered among the rarer English birds, has a frill of feathers round the neck, which is a shield of defence as well as an ornament for display in the regular tournaments which are held; the females, called reeves, lack the distinctive adornment.

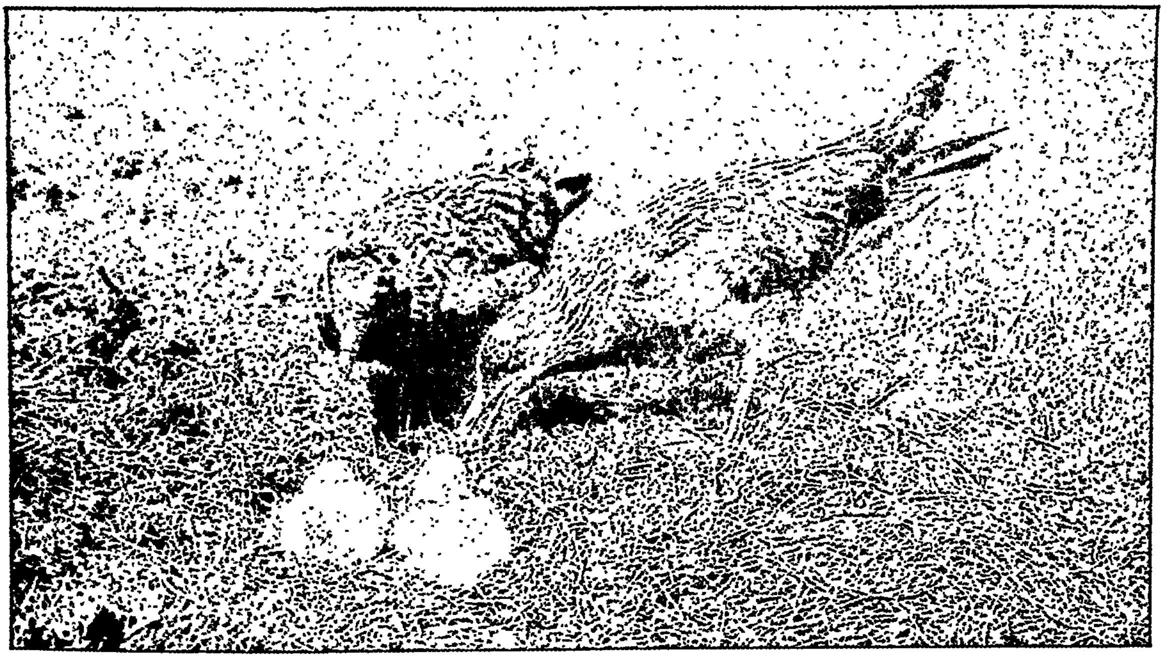


Photo: R. Chislett.

A PAIR OF GREAT SKUAS AND THEIR YOUNG.

The Great Skua is a species related to the Gulls, on which it preys by compelling them to disgorge the food they have just obtained. The similar Arctic Skua, to lead unwelcome visitors away from the neighbourhood of its nest, will cunningly sham a broken wing or leg, luring the intruder to give chase. When at a safe distance from the nest the bird will suddenly rise in the air and fly away.

Voice.

The seat of the voice in mammals is in the larynx, at the top of the windpipe. In birds, however, the vocal cords are at the foot of the windpipe in a special enlargement called the song-box or syrinx. The sounds are due to the rapid passage of the air over the tense cords. In the course of evolution the significance of the voice has broadened out. From a simple parental call it became a means of recognition of any kindred, and in the course of ages it became expressive of particular emotions—emotions of joy and

of fear, of jealousy and of content. While a certain amount of vocal ability is part of the hereditary make-up, there seems little doubt that the gift requires educating. The song of the first year is sometimes what one might call tentative and generalised. It improves with practice and is probably helped by emulation and imitation. The way in which some birds, e.g. skylarks, steal snatches of one another's music suggests the importance of imitation as a factor in educating the vocal powers.

Song.

We have spoken of song as the vocal part in the display of courtship, but it would be wrong to think of it as being no more. Song is, indeed, not confined to the breeding season, but the periods differ with the species; the extent to which the females can sing also varies. It is not possible to draw a sharp dividing line between true song and the notes which constitute the ordinary language of birds, and this gives another reason for not over-emphasising the sexual significance of song.

The definition of song must not be too strictly confined to notes which sound musical to human ears. Outside the ordinary song-bird group, there is quite commonly found some note or cry which is especially associated with the breeding season and which may be regarded as the equivalent of a song. Many of these cries seem harsh and discordant to us, but others have an obvious charm, at any rate, in their native surroundings; amid the rugged beauty of a wild moorland the weird bubbling spring-call of the Curlew is perhaps more appropriate music than the dainty lilt of the sweetest warbler. There are other notes, too, which are not vocal: pigeons, for instance, can clap their wings loudly together in flight, the White Stork rattles the halves of his beak like castanets, and the Snipe "bleats" or "drums" in spring-time, as we have already remarked.

§ 13

NESTING HABITS

Primitive Nesting Habits.

If the earliest birds were arboreal, as we have reasons for believing, the primitive nesting sites were doubtless also in trees. The elaborate structures made by many present-day birds, however, are obviously products of a highly specialised habit which has been evolved in the course of ages. At an earlier stage the eggs would be laid in such natural sites as were available without the necessity of building, and modern examples of a similar habit are not wanting. A species of White Tern, for instance, inhabits tropical islands and frequently deposits its single egg on the strong horizontal leaf of a palm-tree. As Dr. H. O. Forbes says, "The egg is laid in the narrow angular gap between two leaflets on the summit of the arch of the leaf, where it rests securely, without a scrap of nest . . . yet defying the heaving and twisting of the leaves in the strongest winds. The leaf, as in all palms, goes on drooping further and further till it falls, and among the settlers [on Cocos Keeling Island] it is a subject of keen betting, when they see a tern sitting on an ominously withered leaf, whether the young bird will be hatched or not before the leaf falls. The result . . . has always been in favour of the bird; if the leaf falls in the afternoon, the tern will have escaped from the egg in the morning!"

Examples of birds which nest in holes in trees, in accordance with the probably ancestral custom, are the Owls, the Parrots, the Titmice, and of course the Woodpeckers.

The Imprisonment of the Hornbill.

Another hole-nester is the Hornbill, of which various species are found in many tropical lands, and its story is a very strange one indeed. When the eggs are laid and the hen begins to sit, the opening in the tree-trunk is walled up with mud by the cock until only a small orifice remains through which the sitting bird can put no more than her head. The device is doubtless a means of defence against snakes or other enemies, but it involves the imprisonment of the hen during the whole period of incubation. During this time, however, she is by no means left to starve, but is fed assiduously through the "grille" by her devoted mate, who is indeed said to work so hard and to forage so unselfishly that he is worn to a mere shadow of his former self before the task is done.

Among the tree-nesting birds the most primitive type of wholly artificial nest seems to be the platform of sticks or twigs made by such birds as eagles, herons, and pigeons. These structures are often of great size, being added

From "Wild Life in the Tree Tops," by Captain C. W. R. Knight, F.R.P.S.

A LITTLE OWL IN ITS NESTING HOLE.

This small and amusing species has become common in parts of England owing to artificial introduction from the Continent. It is more frequently to be seen in the daytime than some of its relatives.

to year after year. The simplest platforms are quite flat, but others are more or less cup-shaped, as in the case of crows. Finally, this type reaches its highest point in those birds which add a dome-shaped roof.

More Complex Structures.

More promising material is used by most of the small birds which nest in trees or bushes, and with pliable twigs, grasses and roots, moss, and perhaps animal hair, much more complex structures are possible. The Finches, for example, make elaborate and beautiful cup-shaped nests, while others, such as the Wren and the Dipper, make spherical nests which can be entered only by a small hole in one side. In addition to the actual structure there is often a distinct lining of specially selected material; for this purpose small feathers, hair, and fine fibres are greatly favoured, but in the familiar case of the Song-Thrush, for instance, a complete lining of hardened mud is a characteristic feature. Few nests reach such a high development as that of the Tailor-bird of India, so called from its habit of "sewing" leaves together to make a beautiful pouch, a very triumph of the nest-builder's art.

Photo: J. H. Symonds.

THE REED-WARBLER'S NEST IS A BEAUTIFUL CUP-SHAPED STRUCTURE SUSPENDED AMONG THE REEDS.

From nesting in holes in trees to nesting in holes in the ground is an easy transition, and the gap is bridged by birds like the Stock-Dove, which use either site according to the opportunities which a particular district may happen to afford; this bird gets its name from the habit of nesting in holes in the "stocks" of old trees, but among the sand-dunes on many parts of the British coastline it uses rabbit-burrows instead. In similar haunts we may also find another burrow-nester — the bird which Mr. W. H. Hudson calls "the strange and beautiful Sheldrake." Unlike most of the duck family the male Sheldrake is not subject to an "eclipse" moult in the midst of the breeding season, and he is therefore able to stand by his mate, who, furthermore, has a bright plumage similar to his own.

Burrowers.

Other birds which nest in burrows are the Petrels, some Penguins, the Kingfisher, and the Sand-Martin. The last-named nests in colonies, and each pair tunnels many feet into the chosen bank and hollows a little chamber at the end; the Bee-eater makes a similar tunnel, which may be as much as ten feet long. As with holes in trees, a lining may be added, say of grass or other vegetation; the Shelduck, like others of its kind, uses a plentiful supply of down plucked from its own breast, while the Kingfisher lines its nest with an unsavoury collection of fish-

Photo: British Museum (Natural History).

THE WONDERFUL NEST OF REMEZIA, THE PENDULINE TITMOUSE.

Note the funnel-shaped opening leading to the chamber; below is a pocket which is supposed by some to be a roosting-place for the male bird. The nest is made of cotton and seed down, and to the touch resembles a fine felt carpet.

bones and other remains of its prey. The Megapodes go to the extreme of completely burying their eggs either in pits or under specially constructed mounds.

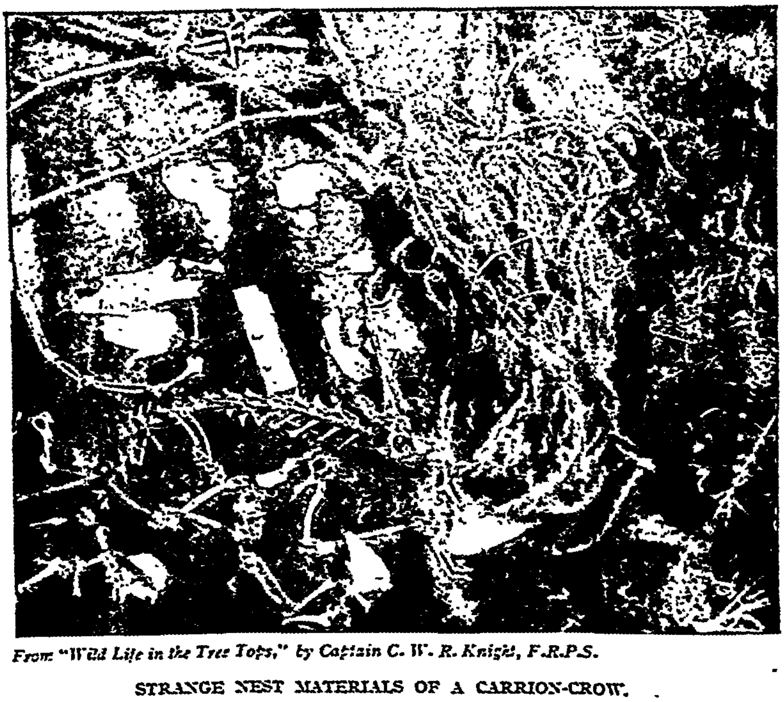
Very many other birds nest either on the open ground or among the long grass and herbage.

Ground-Nesting.

Sometimes there is a well-built nest among grass, as in the case of the Skylark or the Meadow-Pipit; at other times there may be a bulky heap of vegetation or of other material: the Cormorant, for instance, often raises a mound of seaweed, and some kinds of Penguin build a Spartan nest of stones. Still, again, there may be a mere hollow scraped in the ground, as in the case of the Lapwing or of the Tern, perhaps with a lining, a pretence at a lining, or with no lining at all. Finally, the bird may lay its eggs on the ground without any attempt at a nest, as the Oyster-Catcher does among the riverside shingle.

Cliff-Nesting.

Somewhere between the tree-nesters and the ground-nesters we must place those birds which nest on cliffs, for although a nest on a rock ledge may seem in some ways very like a nest on flat ground, the dependence on inaccessibility rather than on concealment makes the habit also akin to tree-nesting. Some of the burrowers, like the Puffins and the Petrels, might well be classed in this group as their holes are usually on precipitous faces, but more typical are those species which breed on the open ledges, like the Guillemot and the Razorbill. A highly specialised type of



From "Wild Life in the Tree Tops," by Captain C. W. R. Knight, F.R.P.S.

STRANGE NEST MATERIALS OF A CARRION-CROW.

Some nests are composed of the bones of departed birds and mammals. There may be also quantities of string, cigarette packets, and even, in one case, a lady's handkerchief.

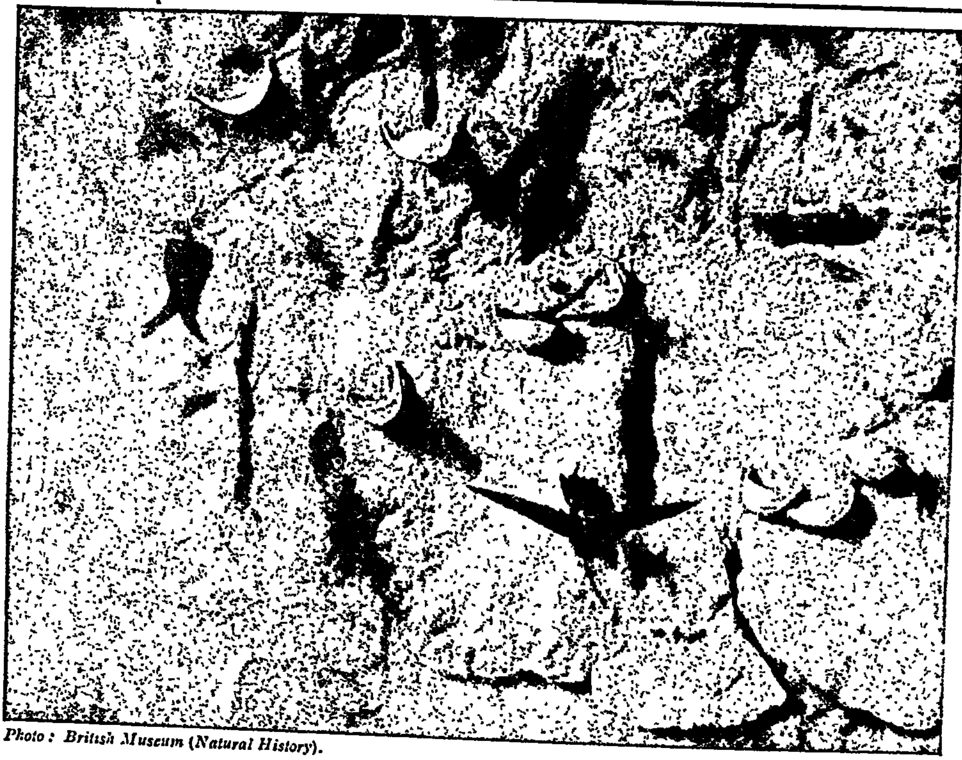


Photo: British Museum (Natural History).

NESTS OF THE EDIBLE SWIFT.

The saucer-shaped nests are made entirely from the saliva of the birds, and form the source of the "birds'-nest soup" which is considered a delicacy in China.

nest, too, is that which is built of mud against the sheer rock face, and for this purpose—as in the House-Martin—the habitations of man are often found to serve as well as natural faces of rock. Sometimes the mud and other materials are made more coherent by the addition of the salivary secretion of the builders, and with the Edible Swift of Borneo this substance, like hardened glue, forms practically the whole structure and is the source of the "bird's-nest soup" beloved of the Chinese gourmet.

The Use of Old Nests.

Many birds return to their old nests and use them again and again, while other kinds habitually build afresh each year. There are birds, too, which commonly use the old nests of other species, with or without additions of their own, although they are not always incapable of building for themselves if faced with the necessity. This habit is not uncommon in the case of birds of prey; the Kestrel, for example, often uses the old nests of crows and pigeons. The Green Sandpiper, belonging to a very different order of birds, uses the old nests of thrushes and other tree-nesting birds—and even squirrel's "dreys"!—although most of its own kin are typical ground-nesters.

§ 14

Chicks and Nestlings.

It is impossible to leave the main question of nesting habits without some reference to the striking differences observable among the newly hatched young of birds. These fall into two well-marked groups in accordance with the condition and stage of development at the date of leaving the egg. Technically these groups are the *nidifugous* and the *nidicolous*, terms which we may translate as nest-quitting and nest-dwelling, though perhaps something of the distinction is conveyed in the two ordinary names "chick" and "nestling." The chick of the domestic fowl is notoriously a nest-quitter; so also are ducklings, whether domestic or belonging to one of the many wild species, and so likewise the young of the plover kind. All these birds leave the egg prepared to take an immediate active part in life; they are open-eyed and lively, able to walk—and, in appropriate cases, to swim—

Photo: "Country Life."

GUILLEMOTS.

The Guillemot, one of the Auks, is common on precipitous parts of the British coastline during the breeding season. A single egg is laid on the bare rock of a narrow ledge. At other times of the year the birds keep to the sea, but dead ones are often washed up on the beach after storms.

and capable of finding their own food with no more than the guidance and protection of the parent. Contrast these with, say, young thrushes —helpless, blind, almost naked, and rather repulsive-looking creatures, which would die miserably without the food their parents so assiduously bring. The difference is, indeed, a most striking one, but some of the nest-dwelling young are not quite so unlike the more active chicks; the nestlings of the birds of prey and of the owls, for instance, are clothed in down and are open-eyed and alert, although they remain in the nest at first and are wholly dependent on their parents for food.

Transporting the Young.

We have an illustration of how some birds make use of their wits in the way they transport their young. In this connection Lord Grey recently told how he watched a Wood-Duck (Carolina) whose nest was a hole in a tree 21 feet from the ground and 300 yards from the water. "Presently the duck flew down from the hole into the grass, and began calling; then one by one the little ducklings came to the edge of the hole and *fell to the ground*. When measured the nest was found to be 2 feet below the hole. For the newly hatched birds to climb that distance, to fall 21 feet, and then follow their mother 300 yards to the water was, I think, a tremendous tribute to the energy of nature."

The female woodcock, when threatened with danger, is known to transport her young, one at a time, to another place. She does so by carrying the young ones with her feet, holding them in her claws, or pressed between her thighs. It is also said that where she nests at a distance from the feeding-ground, she will carry her young to and fro in the morning and evening.

§ 15

The Study of Birds' Eggs.

We cannot here discuss fully the eggs of birds. A wealth of matter for speculation lies in the why and wherefore of size and shape, of texture and colour, and of the numbers forming a clutch. All these characters show wide limits of difference, but on the whole they remain very constant and characteristic for any one species.

Size and Shape of Eggs.

The size of the individual egg is variable, apart from the question of due proportion to the size of the parent bird concerned; this is related in a large degree to the length of the incubation period, while this in turn depends to an important extent on the state of development of the young when hatched, a subject which has already been discussed.

In texture of shell, eggs vary from the brilliantly polished egg of the Tinamous to the soft chalky eggs of the Cormorant, from which the white outer surface can be scraped to show a pale-blue layer beneath. Thickness of shell is also a variable factor, apart from the mere relation to general size.

Egg Coloration.

It is, however, the colours of eggs that have always attracted most attention; some of these are exceedingly beautiful both in tint and in the patterns of marking. Blues and greens are common especially among tree-nesting birds, while ground-nesters usually show neutral brown tones which are most effective for purposes of "camouflage"; some splendid red tones are characteristic of the birds of prey. Markings may be small spots or larger blotches, and they may be evenly distributed or concentrated in a particular zone; fine lines also are found in some cases, witness the Buntings, and in many birds there is a plain marked ground-colour. Pure-white eggs are usually found in species which nest in holes, and this is perhaps of some use in the dark, although the more important point is probably the absence of any occasion for an attempt at "camouflage" coloration. Coloration in many instances serves a protective purpose, and, generally speaking, it is related to some extent to the nature of the bird's environment. There are, curiously, no pure black eggs.

§ 16

Behaviour of Birds.

More than any other creatures, birds have claimed the attention of those who are fond of what Fabre called "scrutinising life." There is often an extraordinary subtlety as well as beauty in their habits. They are big-brained animals, and the senses of sight and hearing are developed to great perfection.

The question is how much in the behaviour of birds we must ascribe to instinctive endow-

ment, that is, to inborn impulsions or hereditary nervous predispositions, and to what extent must we credit the bird with intelligent learning? When a young moorhen swims deftly the first time it touches the water, or dives perfectly when the fit and proper stimulus is forthcoming, we interpret this as instinctive. Its physiological side is a concatenation of reflex actions. Its psychological side is inborn impulse and endeavour. Similarly, when an unhatched lapwing utters its characteristic call-note "peewit" from within the egg, we say this is instinctive—independent of instruction, learning, or imitation.

for learning. The young chick's capacity for rapidly learning simple lessons, mostly associations, has been proved up to the hilt by many experiments.

"In the quiet of the wood one sometimes hears the song thrush breaking snail shells on its stone anvil, and one may easily find the telltale evidences of its appetite. Is this habit, which comes so near using a tool, an inborn gift or has it to be learned? The answer is given by Miss Frances Pitt in her admirable *Wild Creatures of Garden and Hedgerow*. To a young thrush which she had brought up by hand she offered some wood-snails (*Helix nemoralis*), but

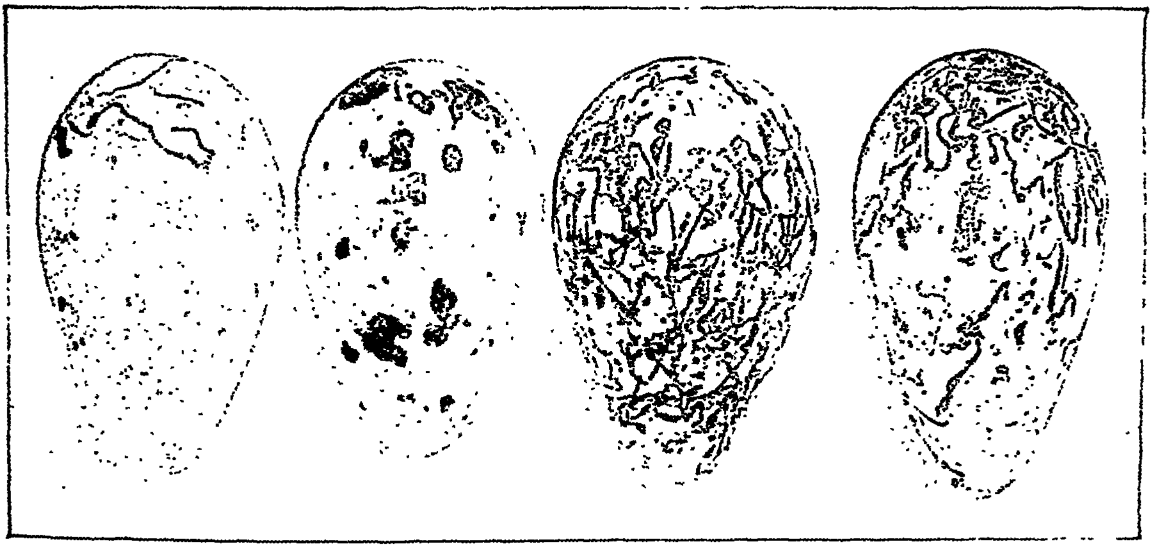


Photo: "Country Life."

EGGS OF THE GUILLEMOT.

These show an extraordinary range of variability, both in marking and in colour. Browns, yellows, reds, greens, blues, and whites are found, and they may be blotched, spotted, lined, or streaked. The shape is believed to serve a useful purpose in preventing the egg from rolling—except in a small circle—and thus from falling off the cliff ledge on which it is laid.

But a different note is sounded in the behaviour of the Greek eagle, which lets the tortoise fall on the rocks from a great height, so that the carapace is broken, or in the similar device of the Rook that lifts the freshwater mussel and lets it fall on the riverside stones. The Herring-Gull sometimes lifts the sea-urchin, or the clam, in its bill, and lets it fall on the shingle, so that the shells are broken. Without necessarily supposing that these birds thought out the expedient, we can hardly avoid the conclusion that they utilise the discovery intelligently. In many cases the bird must be credited with an appreciation of circumstances, with an awareness of what is significant, and with a capacity

he took no interest in them until one put out its head and began to move about. The bird then pecked at its horns, but was bewildered when the snail retreated within the shelter of the shell. This happened over and over again, the bird's inquisitiveness increasing day by day. The thrush often picked one up by the lip, but no real progress was made till the sixth day, when the thrush beat a snail on the ground as it would a big earthworm. At last on the same day he picked up a shell and hit it repeatedly against a stone. He tried one snail's shell after another, until after fifteen minutes' hard work he managed to break one. After that all was easy. He had cracked his first snail. After long trying

he had found out how to deal with a difficult situation. We may say, then, that while a certain predisposition to beat things is doubtless inborn, the use of the anvil is no outcome of a specialised instinct, it is an intelligent acquisition."

The general impression that one gets in regard to the cleverness of birds in such activities as nest-building, capturing booty, and dealing with food is that on an instinctive basis, varying in definiteness, there is built up a superstructure partly due to easy education and subsequent imitation, and partly due to an intelligent appreciation of the lessons of experience. But an appreciation of the relative importance of "nature" and "nurture" requires careful observation and experiment.

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XIII
NATURAL HISTORY

II. MAMMALS

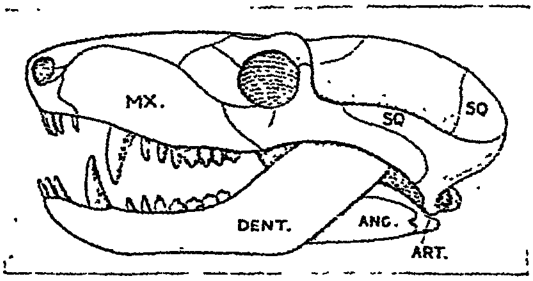
IN an earlier chapter we have dealt with the evolution of animals in general, their haunts or habitats, their everyday functions, their behaviour, and what we have called the dawn of mind. Here we select one class, that of Mammals, and, presupposing what has gone before, we shall discuss them in the main from one point of view—how they are suited to the particular conditions of their life.

Origin of Mammals.

The genealogical tree of animals splits at the top into Birds and Mammals, and these are on quite different lines of evolution. They are not related to one another, except to this extent, that they have a common ancestry among the extinct Reptiles, as we have already seen. For just as Birds sprang from some uncertain stock of bipedal Dinosaurs, so Mammals must be traced back to another extinct Reptilian stock—the Cynodonts. These Cynodonts (also known as Therapsids) occur as Triassic fossils in Africa and North America, and though they were genuine reptiles they had very mammal-like skulls (see figure). Thus the teeth may be distinguished as incisors, canines, and molars, just as in a dog; hence the name Cynodont or "dog-toothed."

The Earliest Mammals.

The earliest mammals were small creatures, the largest no bigger than a rat. The teeth of some of them indicate insect-eating, the teeth of others point to a herbivorous habit. The sharp incisors of some types may have been used to pierce the shells of the eggs of waning Dinosaurs. According to some authorities, many of the early mammals were arboreal, denizens, perhaps, of estuarine and swampy forests. The advantage of such a habitat or mode of life is suggested by the scant vegetation of the arid ground.



SKULL OF A CYNODONT EXTINCT REPTILE. (After Broom.)

The Cynodonts do not seem to have been very far from the direct ancestors of Mammals. The arrangement of the teeth as incisors, canines, and molars is very mammal-like. But the lower jaw remains a complex of several bones, whereas in mammals there is but one bone on each side. Some of the bones are named: MX. maxilla; SQ. squamosal; DENT. dentary; ANG. angular; ART. articular.

Archaic Mammals.

During the geological Middle Ages (Mesozoic) the mammals did not make much headway. Their opportunity was not yet; it was still the Age of Reptiles. The mammals continued a little folk, probably for the most arboreal, keeping out of the way of the huge carnivorous dinosaurs, "stalking terrors such as the world never saw before nor since."

As a matter of fact, however, the giants disappeared, and the pigmies had their innings. With the dawn of the Tertiary time, the mammals began to possess the earth. Their giant enemies had gone, and it is probable that the vegetative conditions became more favourable. The grass began to spread like a garment over the earth.

Progress was at first very gradual; the early Tertiary mammals were still pigmies and with very small brains; but the point is that they began to radiate out into old-fashioned marsupials, carnivores, and hoofed mammals—some of the last attaining elephantine dimensions.

Modern Types of Mammals.

As the primitive and archaic mammals disappeared, there rose up in their stead the mammals of the modern type—with better brains

and more plastic feet and teeth. We refer to such families as Cats, Horses, Elephants, and Monkeys. Their original headquarters were probably in some northern or circumpolar land, which enjoyed a warm and equable climate.

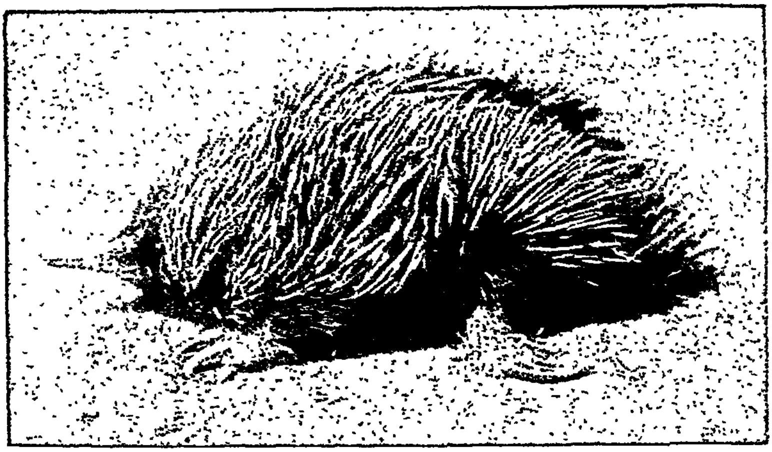


Photo: W. S. Berridge.

ECHIDNA OR SPINY ANT-EATER.

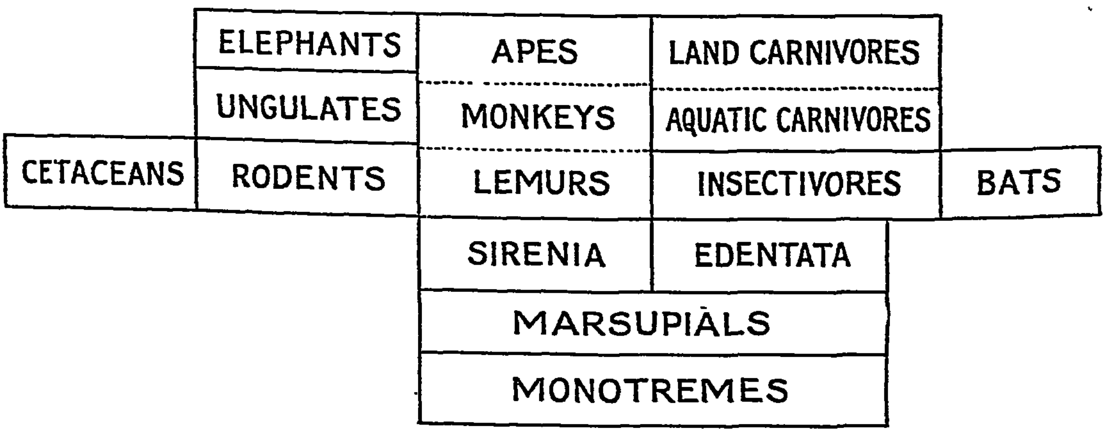
This primitive egg-laying mammal ranges from Australia through the Papuan region. There is a related genus, Proechidna, in New Guinea. The body is covered with strong spines mingled with hair. There are three massive claws suited for burrowing. The mouth is absolutely toothless; the tongue is worm-like; the food consists mainly of ants and other insects. When the egg is laid, the mother takes it in her mouth and places it in her pouch. The shell is broken by the emerging young one. After a time the mother removes the young one from the pocket and leaves it in a burrow while she hunts at night. But she restores it for feeding purposes. The cerebral hemispheres are well convoluted, and the creature is not stupid. It is imperfectly warm-blooded, and hibernates.

§ 1

The Egg-laying Mammals.

There are three strange Australian mammals that occupy a position quite by themselves—the Duckmole (Ornithorhynchus), the Spiny Ant-eater (Echidna), and another ant-eater (Proechidna). They differ from all other mammals inasmuch as *they lay eggs*, thereby harking back to the habit of many reptiles. In the form of their shoulder-girdle, in their relatively large eggs with much yolk, in their very variable temperature, and in many other ways they betray their affinity with reptiles, and they must be regarded as very primitive mammals persisting from ancient days.

The Duck-mole, or Duck-billed Platypus (18–20 inches in length) lives beside lakes and streams, and grubs at the bottom or among water-weed for small animals, which it collects in cheek-pouches and chews at leisure with its eight horny tooth-plates. For its true teeth do not last for more than a year. Its fore-feet are webbed, and it is a clever swimmer and diver. But the feet are also clawed, and the quaint creature makes a long burrow in the bank, with two openings, one above and one under the



GROUPING OF THE ORDERS OF LIVING MAMMALS.

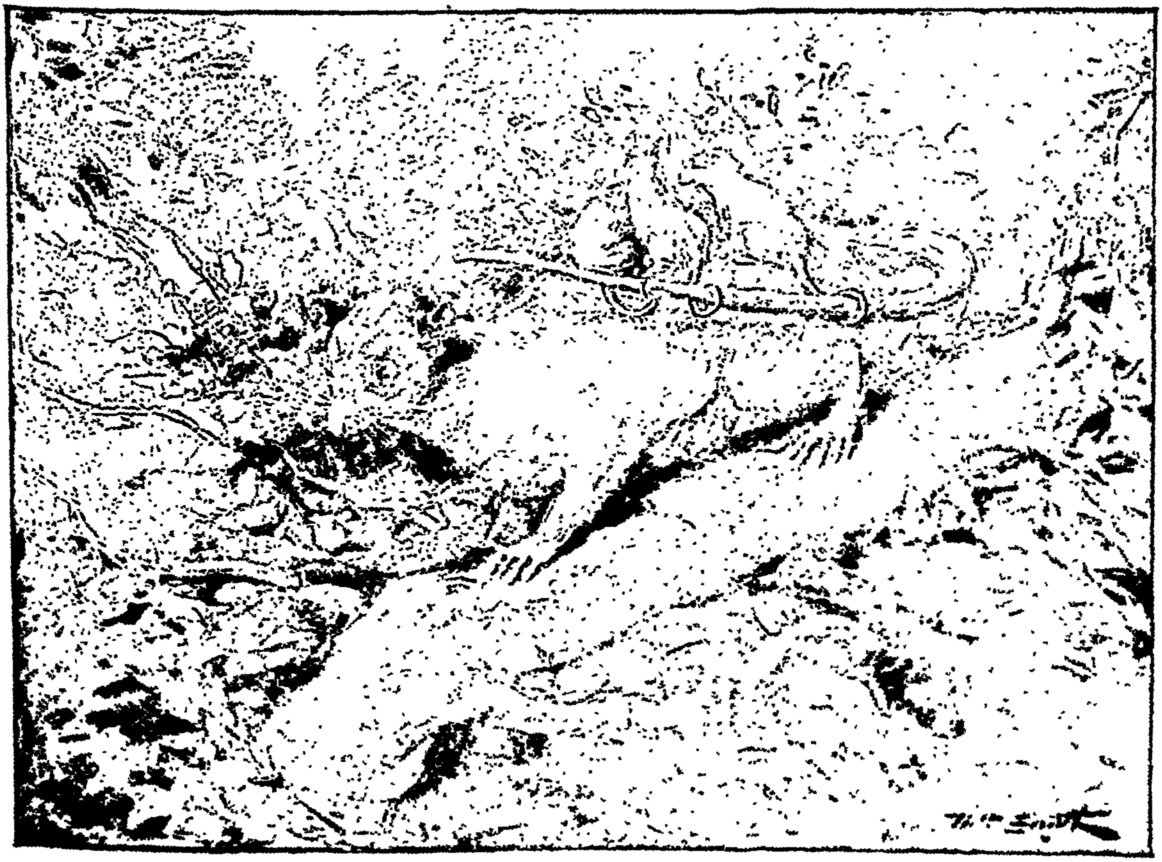
At the bottom of the scale are the primitive, egg-laying Monotremes, represented by the Duckmole and the Spiny Ant-eater. Above them are the pouched Marsupials, of which the Kangaroo is a type. The remaining Orders fall within the group of Placentals, in which there is an intimate connection between mother and unborn young. Of these, the Edentates (e.g. the Sloth) and the Sirenians or "Sea-Cows" may be ranked as archaic forms. Higher up we have the Insectivores (e.g. the Hedgehog); the aquatic Carnivores (e.g. Seals) and the terrestrial Carnivores (e.g. Lion), the Rodents (e.g. the Rat); the Ungulates or hoofed quadrupeds, and the Elephants: and, marking extremes of mammalian life, the winged Bats and the open-sea Cetaceans or Whales. Finally, there is the great Monkey stock, including the old-fashioned Lemurs, the true Monkeys, and, highest of all, the Anthropoid Apes.

water. The jaws are flattened like the bill of a duck and covered with soft sensitive skin, expanded into a flexible collar where the bill joins the rest of the skull. The eyes are small; the ear-holes are closed by a flap; the tail is strong and helps in swimming; the brownish fur is short and soft; the animal can roll itself up into a living ball, and sleeps in this attitude. In the recesses of the burrow two eggs are laid, each about three-quarters of an inch long, enclosed in a flexible white shell, through which the young one has to break its way. There are no teats or mammæ for the young one to suck, and the milk simply oozes out by numerous pores on a bare patch of skin on the ventral surface of the mother. It is licked up by the offspring—a very primitive arrangement.

The Spiny Ant-eaters live in rocky regions and burrow rapidly with very strong claws. They seem almost to sink into the ground. When they get among rough herbage they take firm hold with their feet and are very difficult to dislodge. The snout is prolonged into a slender tube, through which a mobile, sticky, worm-like tongue is protruded on the ants which form the staple food. No traces of teeth are to be seen, even in the embryo. As in the Duckmole, the male has a well-developed spur on the hind-leg, perforated by the duct of a gland, but its use is obscure. The egg seems to be placed by the mother in a temporarily developed pouch, which is said to be comparable to a greatly enlarged teat of the type seen in the cow. Within this pouch the milk oozes out. There are no stranger animals in existence than the Duckmole and the Spiny Ant-eaters. They might almost be called "living fossils."

§ 2

The second grade among present-day mammals is that of the Marsupials, which are now confined to Australia except in the case of



OPOSSUM AND YOUNG.

In some of the Opossums, especially the smaller species, the mother carries the young ones on her back, with their tails twisted round hers. Azara's Opossum may carry eleven and yet climb quickly. The habit may occur even when there is a pouch, but that structure is generally absent in the Opossum family (Didelphyidæ). The Opossums are also peculiar in being confined to North and South America.

two families—the American Opossums and Selvas. In most cases the female has a pouch or marsupium developed around the mammæ, and in this pocket the prematurely born young are stowed away and carried about till they are able to fend for themselves. In many opossums the pouch is absent, and the mother carries the young ones on her back, with their tails coiled round hers—a quaint device. In marsupials in general, the young ones are born very helpless, unable even to suck. The mother takes her young one in her mouth, and puts it into her skin-pouch, within which lie the teats or mammæ. The mother adjusts matters so that the mouth of the young one closes on a teat, which then swells a little, and, as the prematurely born offspring cannot suck, she injects the milk down the gullet by contracting a special musculature. The milk might "go down the wrong way" and choke the offspring, were it not that the glottis (the entrance to the windpipe) is shunted forward in the young creature so as to press against the posterior nostrils at the back of the mouth. Thus breathing goes on undisturbed by the injection of milk. A similar adaptation is seen in the Baleen Whale—another mammal—when it is rushing through the water with its great mouth agape, and also in the Crocodile—a reptile, not a mammal—when it is drowning its prey.

The Pouch-bearing Mammals.

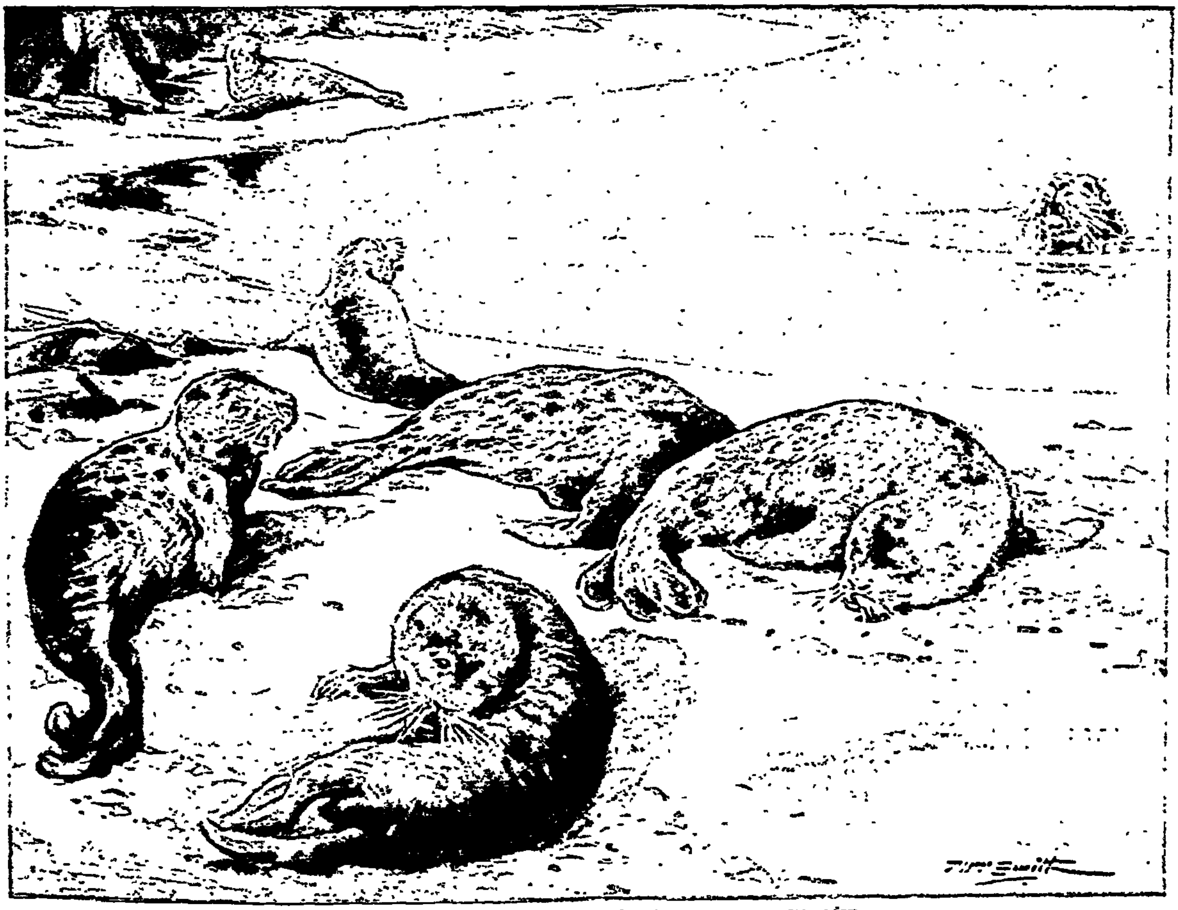
As an individual example of a marsupial we may take the Opossum (Didelphys)—which Mr. Ingersoll calls a "grey, grunting, snarling, pilfering, dunder-headed, and motherly creature." It is not a good type, for it is American, not Australian, and in most of the species of the genus the pouch is conspicuous by its absence. But the Opossum was the first marsupial to be known to the civilised world. Opossums are mainly arboreal and insectivorous, but there is considerable variety of habitat and diet. They are notorious for playing 'possum, and we wish to incorporate what Ingersoll says of a pouched species in regard to this puzzling "ruse" in his *Wit of the Wild* (1921). A mother opossum will face up to an enemy that threatens her half-grown young, and male opossums will fight to the death at the courting time. So the creature does not lack courage! If it detects danger in advance—and every hand is against it—it will hasten up a tree and hide. So the creature does not lack discretion. "In other cases—just what or when it would be hard to define exactly, but apparently in the presence of something so large as to make resistance idle—the animal, when attacked or cornered, will fall limp and 'dead.' You may roll the creature about with your foot, explore the pouch, pick it up and carry it by its tail, offer it almost any indignity, and it will, in most cases, neither resist nor complain; but take your eye off it as it lies upon the ground, and it will soon jump up and scuttle away, or if you pick it up carelessly enough to give it a chance it may nip you savagely." But the question is inevitable: "Of what service is the ruse?" Would the carnivore or the bird of prey that liked opossum flesh—dogs won't touch it—care whether the creature is dead or pretending to be dead? Mr. Ingersoll's ingenious suggestion is that playing 'possum is an instinct that arose in the geological Middle Ages in relation to the dull-witted big reptiles—as a rule, land reptiles do not feed on carrion—and that it persists nowadays as an anachronism in circumstances where it is oftener fatal than protective.

Playing 'Possum.

§ 3

The third grade of modern mammals includes the carnivores, the hoofed animals, the monkeys, and so on—to all of which the term "placental" is applied. In adaptation to the difficulties of terrestrial life, there has been an evolution of viviparous arrangements. The Monotremes, as we have seen, lay eggs; the Marsupials bring forth their young prematurely; the Placentals have established a more or less prolonged ante-natal partnership between the mother and the unborn young. The linking structure between the two is the placenta, which brings some of the blood-vessels of the unborn young (or fœtus) into close contact, although not union, with the blood-vessels in the wall of the mother's womb (or uterus). No solid particle, unless it be a living microbe or a wandering white blood-corpuscle, can pass from the mother to the offspring, but there is a transfusion of fluid and gaseous material between the two partners. What does the offspring get from its mother? Dissolved nutritive material, oxygen, water, salts.

The Placental Mammals.



YOUNG OF COMMON SEAL ON THE BEACH, SHETLAND.

The Common Seal (*Phoca vitulina*) is a sociable animal, living in small herds where the conditions are suitable. On British coasts these safe places are rapidly disappearing, for the young, left on shore by the mothers when they go a-hunting, are often killed. The drawing gives a fine impression of the charming attitudes of the young creatures.

and some subtle chemical messengers called "hormones." What does the offspring give to the mother? Dissolved waste-materials, carbon-dioxide, watery fluid, and again some "hormones." The mother gives much and gets little; but it seems justifiable to say that the internal secretions or hormones contributed by the unborn offspring to the mother assist in her health and enable her to make the most of her food. Before the young one is born, chemical messengers have been carried by the blood to the mother's mammary glands, so that they are stimulated to begin the production of milk. There is much of this physiological telegraphy in the business of living.

It is probable that the long-drawn-out antenatal development has greatly favoured the improvement of the brain. Thus everyone knows how wide-awake a foal is after its long sleep of eleven months within its mother's womb. But it must be added that the structure of the brain in placental mammals had got on to lines much more promising than in marsupials. Granting this, we seem justified in saying that the prolonged gestation, plainly adapted to the exigencies of terrestrial life, opened up the possibility of being born with an advanced brain equipment. In the same way, the prolonged infancy, familiar in mankind, has its great rewards as well as its great risks.

It is interesting that mammals should bear a name that emphasises the mother's breasts, and this strikes a true biological note. For the success of mammals is wrapped up with their maternal care, taken in conjunction with improved brains. To the difficulties and limitations implied in the struggle for existence, some mammals have answered back by evolving teeth and horns, others by evolving swiftness, others

by evolving armour, others by evolving wings—but the answer back that is common to them all is the maternal sacrifice and devotion.

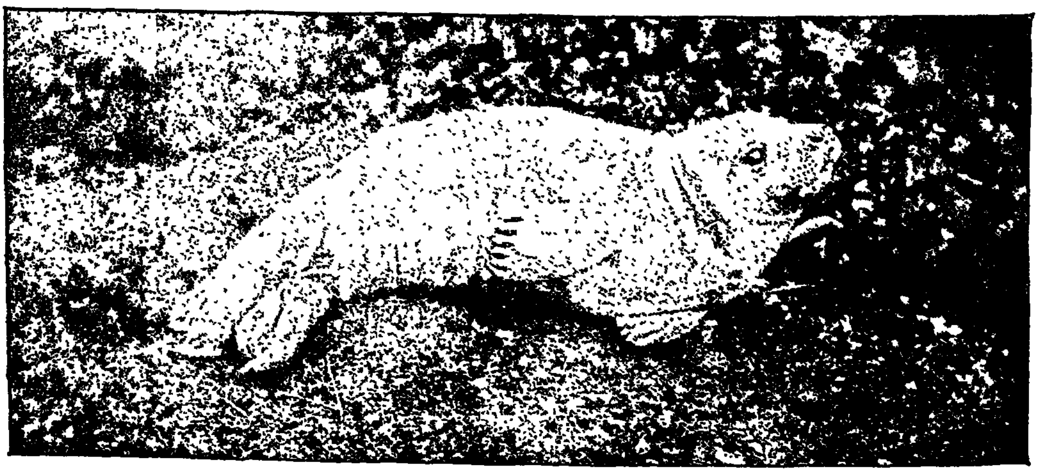
§ 4

Many Habitats.

Like the reptiles before them, mammals have sought out many habitats, and have become adapted to as many modes of life. Perhaps it was in the trees that they served their apprenticeship; in any case they have tried all possible haunts, entering every open door of opportunity. This is what Professor H. F. Osborn calls "adaptive radiation," and he distinguishes as many as twelve habitats. (1) There are terrestrial mammals, walking like the elephants, running like the antelopes, jumping like the kangaroos. (2) But some are burrowers as well as runners, as rabbits well illustrate. (3) Then there are thoroughgoing burrowers, like the moles, which have conquered the underground world. (4) Some are as much at home in water as on dry land; we think of the roving otter and the polar bear. (5) Perhaps a separate division may be made for those mammals that frequent streams, after the manner of beavers and the familiar water-vole—which can hardly be saved from its popular name of "water-rat." (6) The shore of the sea is the habitat of seal, sea-otter, and walrus. (7) The open-sea mammals are the cetaceans large and small, from whalebone whale to porpoise. (8) Professor Osborn takes the deep-diving finback whales as examples of mammals that actually explore the great abysses, but this is perhaps stretching a point. (9) Then there are the betwixt-and-between mammals transitional between arboreal and terrestrial life, like the macaque monkeys and the gorilla. (10) Strictly arboreal types are well represented by squirrels, tree-sloths, and lemurs. (11) The volplaning "flying squirrels" and "flying phalangers" form another interesting betwixt-and-between group, essaying the conquest of the air in their daring parachuting from tree to tree. (12) Finally, the bats are true fliers—aerial mammals.

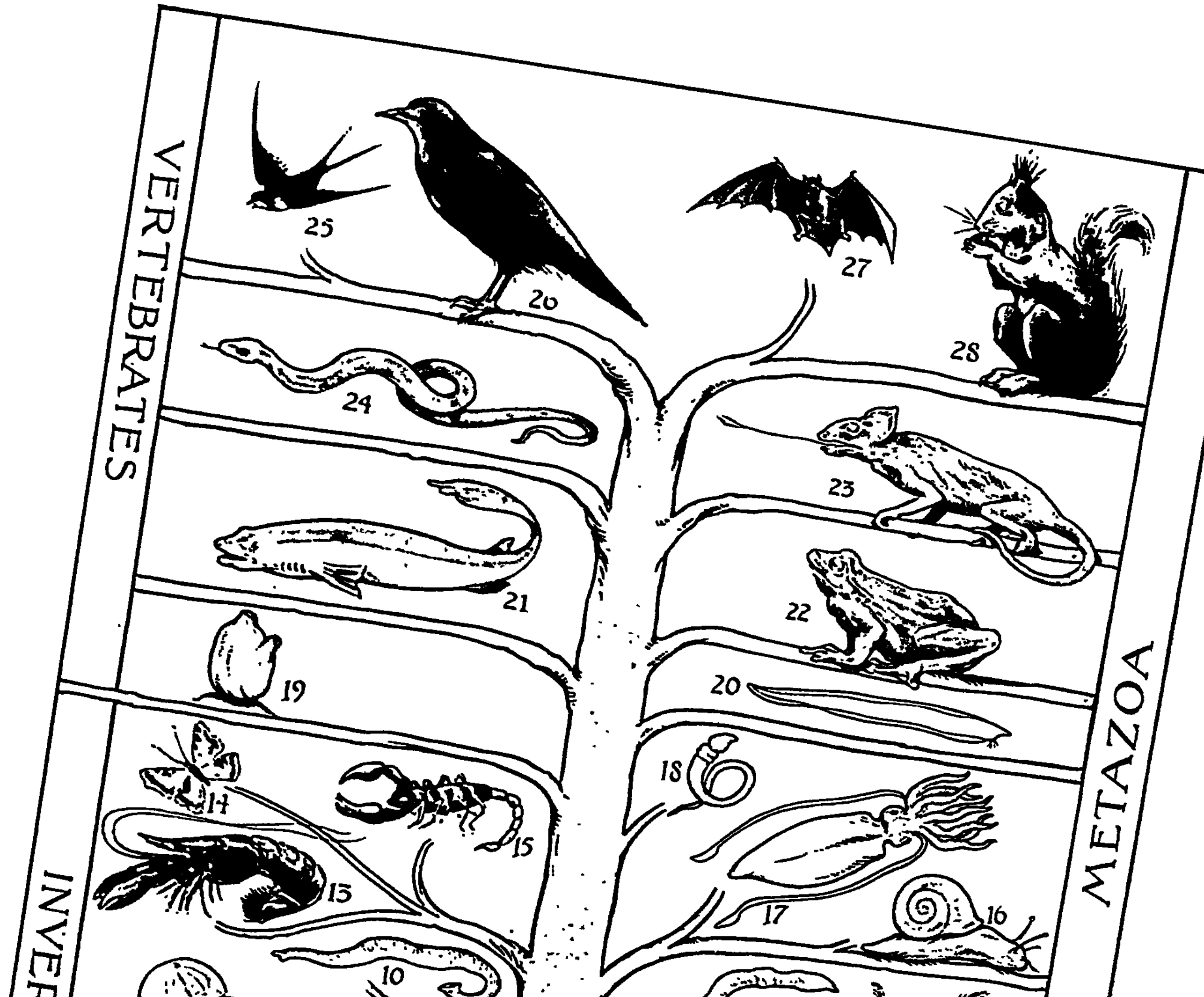
It is useful to recognise this variety of habitat, for it shows how diverse the life of mammals must be, and the impression of diversity grows when we remember that in most habitats there are several distinct possibilities of food-getting. Thus a mole is a carnivorous burrower, while a vole is a vegetarian burrower; a small bat is an insectivorous flying mammal, while a big bat is usually a fruit-eater. It is very interesting to find that almost every haunt and diet illustrated by mammals has also been utilised by reptiles, either living or extinct. This suggests that evolution has proceeded on an ever-ascending spiral.

Birds and mammals have evolved, as we have already said, on entirely different tacks, but it is not unprofitable to notice that they have often made the same kinds of experiments.



YOUNG OF BEARDED SEAL.

As in many other cases, the young of the Bearded Seal (*Erignathus barbatus*) has a uniformly light-coloured coat—in this species practically white. It is retained for some weeks. The young of the Harp-Seals (*Phoca grœnlandica*) are also called "white-coats." When the young one is lying exposed on the ice there may be protective value, or, more probably, physiological comfort, in being white. The Bearded Seal is a North Atlantic species, occasionally visiting British shores.



PICTORIAL REPRESENTATION OF THE GENEALOGICAL TREE OF ANIMALS.

1. A plant, indicative of the Vegetable Kingdom—on another line of evolution.—2 and 3. Chalk-forming animals or Foraminifers.—4. A parasitic Gregarine.—5. The Night-light Infusorian, Noctiluca.—6. The Bell-Animalcule, Vorticella. All these are Protozoa, unicellular animals. Multicellular animals are called Metazoa.—7. Crumb-of-Bread Sponge.—8. A Sea-Anemone, and 9. A Jelly-fish—both Cœlentera or Stinging Animals.—10. A Leech, and 11. An Earthworm, both Annelids.—12. A Brittle-Star, representing Echinoderms.—13. A Lobster, representing Crustacea.—14. A Butterfly, representing Insects.—15. A Scorpion, representing Arachnids.—16. A Snail, and 17. A Cuttlefish, both representing Molluscs.—18. Balanoglossus, a worm-like type intermediate between Invertebrates and Vertebrates.

Among Vertebrates: 19. A Sea-Squirt or Tunicate.—20. A Lancelet.—21. A Shark (Fishes).—22. A Frog (Amphibians).—23. A Chameleon, representing the Lizard order of Reptiles.—24. A Snake, another type of Reptile.—25. Swallow, and 26. Rook, representing Birds.—27. Bat, and 28. Squirrel, representing Mammals.

Photo: F. R. Hinkins & Son.

COMMON MOLE (*TALPA EUROPÆA*).

One of the conquerors of the underworld, adapted to its subterranean life in its barrel-like shape, reduction of friction (e.g. no external ears), elongated muzzle, shovel-like hand, strong breast muscles, and powerful neck for tossing the earth. The hair has no "set"; the minute eye is well concealed. The mole is a representative of the dwindling order of Insectivora, but its range still extends from Mull to Japan.

The Ostrich is a running bird, the Antelope a running mammal; the Owl is a nocturnal bird, the Hedgehog is a nocturnal mammal; the Storm-Petrel is an open-sea bird, the Dolphin an open-sea mammal; the Sand-Martin is a burrowing bird, the Mole a burrowing mammal; and so on. For a long time there were no flying mammals to vie with the flying birds; but eventually there was the evolution of bats, doubtless from an arboreal insectivorous stock.

Aquatic Mammals. It is instructive to consider some of the thousand and one ways in which mammals are specially adapted to the various haunts and conditions in which they live. But only a few illustrations can be given, beginning with aquatic mammals. In whales the tail has been transformed into a propeller, which sculls the water first to one side and then to the other, and great speed is attained in swimming and diving. With these swimming powers is associated the almost worldwide distribution of many cetaceans, like the Sperm Whale and the Southern Right Whale. In seals the hind-limbs are bound up with the tail, a conjoint propeller which churns the water from side to side being the result. In the walrus the hind-limbs are helped by the great paddle-like fore-limbs, which are also used for clambering on the slippery ice. The Common Seal has a remarkable way of moving on land. It arches up its body, bringing the hind-limbs and tail towards the head, and then suddenly straightens itself away, thus jerking the body forwards. In swimming the Beaver uses its trowel-like flattened tail; the Duck-mole has webbed fingers; the Water-Shrew has special hairs on the sole and toes of its hind-foot, which are spread out like a comb in swimming, but become appressed when the little creature runs on land. The long tail of the Water-Shrew serves as a rudder; it is somewhat flattened vertically and bears a fringe of long hair on its ventral surface. The adaptations to aquatic life are many: thus there is often a reduction of friction by the disappearance of external ears, as in seal and whale; hair is almost quite gone in cetaceans, though those that remain about the mouth may be very useful in their exquisite tactility; the absence of hair, which normally serves as a non-conducting robe, is compensated for by the development of a layer of blubber—just an exaggeration of the deposit of fat (*panniculus adiposus*) which is formed under the skin of most mammals (the Common Hare a noteworthy exception); the mother whales have an arrangement for giving their baby a huge mouthful of milk at a gulp, for suckling cannot be very easy in the open sea. It is said that the Northern Right Whale may remain under water for an hour and twenty minutes, and in adaptation to this prolonged immersion there is a huge chest cavity, and also a development of wonderful networks (*retia mirabilia*) of arteries which store pure blood and keep the tissues oxygenated when respiration in the ordinary sense has come to a standstill. According to Lillie, a rorqual may remain eight to twelve hours under water, and it is possible that in this case a sort of skin-respiration (familiar in frogs, for instance) is effected by means of numerous very vascular longitudinal ridges on the underside of the rorqual's throat. Besides the positive fitnesses,

Photo: British Museum (Natural History).

"FORTRESS" OF THE MOLE (in cross section).

The large mounds of earth noticeable where moles are abundant are the "fortresses," while the smaller mounds are made by the earth thrown up during the construction of the "runs." The sexes build separate fortresses, and that of the female—an example of which is shown here in section—is the larger, being used as a nest for the young.

of which some illustrations have been given, there are negative adaptations. Thus, in thoroughly aquatic mammals, such as whales, there can be no smelling, and the olfactory organ is naturally degenerate. For what is useless is rarely conserved. Or, again, the cetaceans, which have their eyes continually washed with water, have no third eyelid—which is used in other mammals, except man and monkeys, for cleaning the front of the eye.

§ 5

Subterranean Mammals.

As life on the surface of the earth is attended by great risks, which have to be met by special adaptations, it is not surprising that many mammals should seek refuge underground or should combine terrestrial and subterranean habits. Of adaptations to thoroughgoing subterranean life the Mole is perhaps the finest instance. Its hand is turned into a strong shovel, with which it literally "swims" in the earth. To the inside of the thumb there is a special sickle bone, which broadens the digging surface. The breast muscles are like an athlete's, and those of the very short neck are well suited for tossing the earth. There are no projecting ear-trumpets, for these would be much in the way; the eye, unnecessary in darkness, is reduced to a pin-head size ($\frac{1}{25}$ of an inch in diameter), and is protected from injury by being well hidden in the hair of the head; the position of the nostril rather under the tip of the snout and a lip-fold in front of the mouth serve to keep the earth out; the hair of the body has no "set" and is easily kept clean, moreover it does not get disordered when the burrower moves backwards; the crowns of the back teeth are covered with sharp cusps, most admirably suited for crunching insect larvæ and the like. Truly the Mole is a bundle of adaptations. The Common Mole burrows in soft soil, and its hand is therefore broad; but the Cape Golden Mole and the quite unrelated "Marsupial Mole" burrow in hard soil, and their hands are very narrow, with a great strengthening of two of the fingers. This is plainly as it should be, and the impression of fitness grows when we consider details. Thus the Marsupial Mole, which presses its head into the earth, has its neck vertebræ solidified.

We have mentioned the Mole's adaptation to subterranean life, but this extraordinarily

interesting mammal claims further attention. It is not only a bundle of adaptations, it is an antiquity; it was long ago one of the discoverers of the underworld; it ranges successfully from Mull to Japan; it lives an unusually strenuous life; it has the charm of elusiveness and idiosyncrasies. It has four modes of locomotion. Ordinarily it "swims" deeply in the earth, using its hands to force the earth to either side, and scratching backwards with its hind-feet. It can burrow for a considerable distance without making a molehill. Secondly, when there is food, e.g. leather-jackets (the larvæ of the crane-fly or daddy-long-legs), to be got near the surface, the mole works along in a shallow groove, often breaking to the open, and leaving a discernible track. In this shallow burrowing, it uses its head and strong muscular neck a good deal, tossing the earth upwards and to the side, in a way that recalls the old name "moudie-warp" or mould-tosser. Thirdly, it can run about on the surface at the rate of about 2½ miles an hour, and the pairing takes place above ground. It must also be able to trot along in those underground runs which have some permanence, e.g. the "bolt-run" from the headquarters. As to this so-called "fortress," it consists of a roughly spherical nest about the size of one's head, filled with leaves and grass. Above and around this resting-place there is a mound made of the earth which has been dug out, and traversing this there are tunnels or galleries which were made in transporting the excavated earth and may connect with the bolt-run or other radiating paths. No two "fortresses" show the same plan of galleries; their symmetry and significance have been exaggerated; they are simply the necessary outcome of making a comfortable resting-place and piling up the excavated material. According to some naturalists, an elaborate "fortress" is made by the males only. The sexes live apart, and the well-lined nest made by the female in May is usually under an inconspicuous hillock. The young ones, usually four or five in number, are pink and naked to start with, and very helpless. But the development is unusually rapid, the infantile period being telescoped down, and the offspring are able in five weeks to follow their mother and begin mining. The full-grown males are very combative; indeed, there is a good deal of suppressed fury in any mole. Everything they do is done with vigour and zest —moving, feeding, fighting, everything. A mole has been known to displace a nine-pound brick on a smooth surface, which for an animal weighing three ounces is equivalent to a man of twelve stone moving an object weighing 3 tons 12 cwt. (Frances Pitt, *Wild Creatures of Hedgerow and Garden*, 1920).

The Mole.

The Mole's vigour must be correlated with its extraordinarily good digestion. A mole can

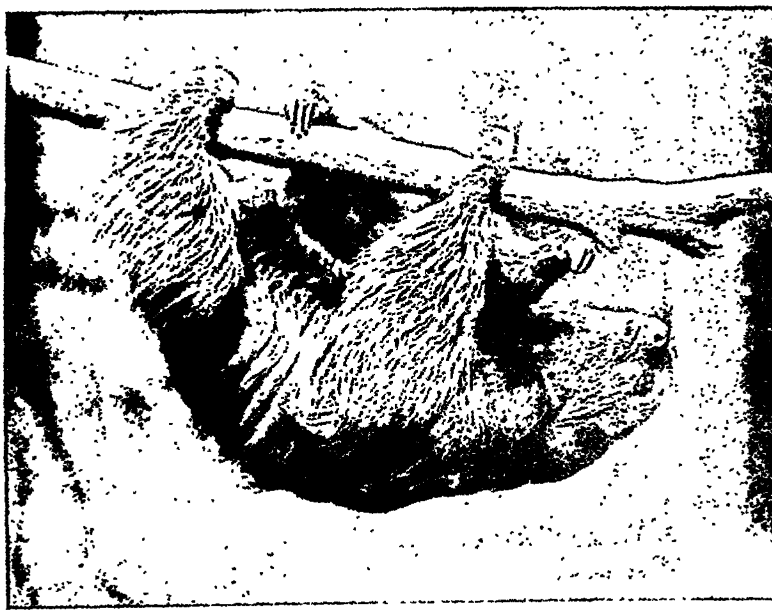


Photo: W. S. Berridge.

TWO-TOED SLOTH OR UNAU.

This old-fashioned type (*Cholœpus didactylus*) lives in the forests of South America, e.g. in Nicaragua. It is highly specialised for arboreal life, moving slowly about back-downwards along the under side of the branches, holding on with the recurved claws on the two fingers and three toes. On the ground it moves awkwardly. It feeds on leaves, and has a stomach with several chambers. The hair is coarse and shaggy and affords a basis for the growth of a unicellular green alga. The teeth are simple pegs without enamel, and seem to be confined to one set. The two-toed Sloth has usually six neck vertebræ and the three-toed Sloth has usually nine, thus illustrating divergence from the normal mammalian number seven.

Photo: W. S. Berridge.

AMERICAN GREY SQUIRREL (*SCIURUS CAROLINENSIS*) COMING DOWN A TREE.

An attractive and beautiful native of North America with habits similar to those of the Red Squirrel. A large nest is built on or in the tree, and there are usually two litters in the year. The creatures show great enthusiasm in hiding stores, including single nuts, in the ground. When pursued they press themselves flat and quiet on a branch, or take daring leaps from tree to tree. Many small colonies have established themselves, sometimes from Zoological Gardens, in Britain; and the diffusion on the shores of Loch Long shows the danger of introduction. The animals are very delightful in the London parks, but they may do enormous damage in woods and forests. The pet of confinement is apt to be the pest of the open.

easily dispose of its own weight of earthworms in a day, and adults require food every three or four hours. A mole that was fed with forty earthworms late in the afternoon was found dead next morning with an empty stomach!

§ 6

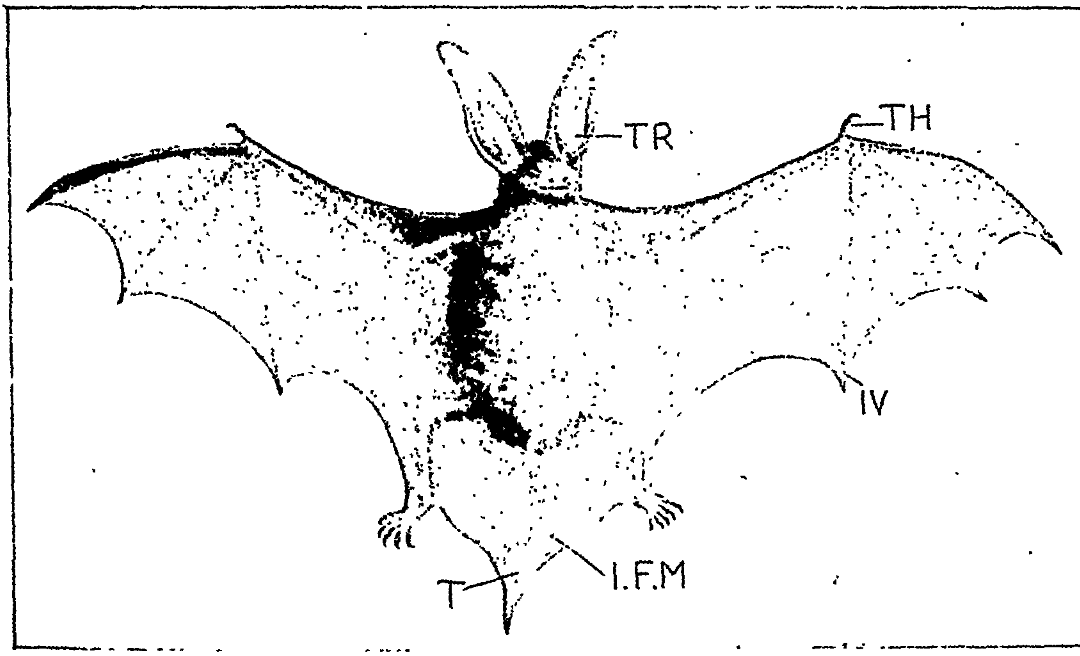
Whether the earliest mammals were arboreal or not, it is a mode of life which many have adopted, and it has obvious advantages of increasing the freedom of movement, of securing a relatively safe retreat, and of making a nest a possibility. In many cases, as in a wild cat, the sharp claws are well suited for holding on to the branches. The Squirrel runs up the trunk, gripping with its claws, but looking as if it did not need to hold on; and its bushy tail is of use as a rudder when it takes an adventurous leap from tree to tree. In some cases, however, there are special attaching structures; thus the extraordinary lemur called the Tarsius Spectre has disc-like suckers on its fingers and toes. Sometimes there is a splitting of the hand and foot which gives the limb a secure grip of the branch, and the same result may be reached by having an opposable first digit, like our own thumb. The Tree-Sloths show yet another method, for their claws are greatly elongated into hooks, and by means of these they move cautiously along, back downwards, hanging to the underside of the branches. It is interesting to notice how many features of these strange creatures have been altered in relation to their upside-down mode of progression. Thus they can bend their head round so as to look downwards over their shoulder; the neck is very mobile, and in some species has nine instead of the usual seven vertebræ; the shaggy hair hangs down in a unique way, and its suggestion of a mass of fibrous plants may be enhanced by the presence of a green Alga. One of the most

Arboreal Mammals.

Photo: Douglas English.

NUTS GNAWED BY SQUIRRELS.

The holes in the empty shells show the neat work of the chisel-edged incisor teeth, and also, in most cases, the marked economy, for the aperture is not made larger than is necessary to let the kernel out.



THE LONG-EARED BAT.

Long-eared Bat (*Plecotus auritus*), a common British bat, which does good work in destroying injurious insects. It is a playful creature, not difficult to tame. The ear-trumpet is larger in proportion than in any other animal, and may be 1½ inches long. The body, not counting the tail, is about 2 inches in length. In the ear, as in many other bats, there is a very strong development of the forward flap or tragus (TR), which is represented by a small anterior lobe on our ear-trumpet, guarding the entrance. The projecting clawed thumb (TH) is clearly shown, and the fourth digit (IV), corresponding to our little finger. Between the hind-legs, supported by the tail (T), there is an inter-femoral membrane (I.F.M.), a basket of skin against which the bat presses its insect booty when it is killing them during its flight.

effective adaptations to arboreal life is the most familiar—namely, the prehensile tail of many monkeys. In the Spider Monkey (Ateles) the tail is used not only to support the whole body, but actually as a "fifth hand" for grasping the food. Again, we get an impression of the plasticity of animal structure—the same part being turned and twisted to so many different uses.

It may be doubted if there is any climbing mammal with more all-round attractiveness than the Common Squirrel. It is small without being pigmyish; the bushy tail balances the body; the rich brown-red upper colouring is very pleasing; the ear-tufts present during the colder half of the year make the creature look even more alert than it is; its movements take one's breath away.

The Squirrel.

Its table manners are perfect, for it sits upright, holding its food daintily in its hands; it neatly unshells the kernel of the nut; it even removes the thin outer pellicle before it begins to munch. Everyone knows how the squirrel passes from tree to tree, but it may also press its body against the stem and remain perfectly still. When it sleeps it uses its tail as a blanket. The security of its life probably adds to the gaiety of its disposition, for it is one of the playing animals, enjoying what looks like "tig" among the branches. Squirrels usually pair early in spring. Two or three blind and naked young ones are born in a large nest of moss and leaves and twigs, which the monogamous parents build among the branches. There is strong maternal care and courage, and when danger presses the mother may carry one baby after another in her mouth to some place of safety. There is considerable instruction in athletics and woodcraft.

When winter comes the Squirrel does not hibernate, though on a very cold morning it may sleep late within the hollow tree. It still finds seeds and shoots to eat, and when these are scanty it searches about for the caches of nuts it made in September and October—and forgot all about! Too much has been made of the Squirrel's thrift.

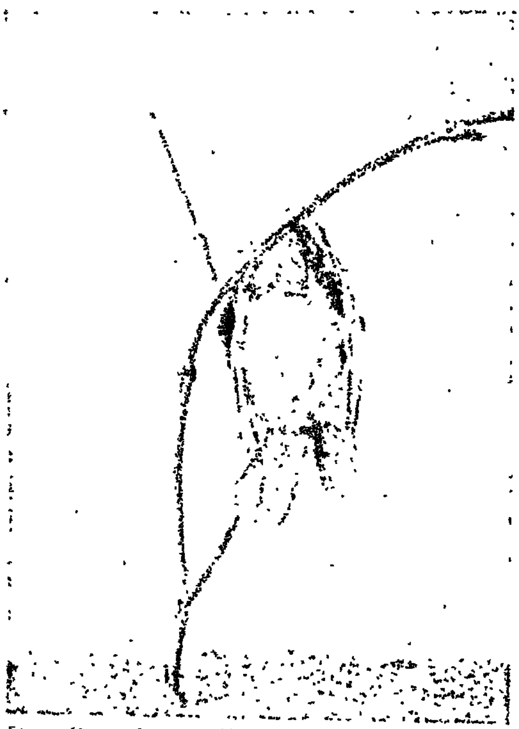
§ 7

Although the scanty fossil remains of Bats have revealed nothing as to their ancestry, it

seems safe to say that they evolved from an Insectivore stock. Specialised as they are for flight, they show numerous affinities with tree-shrews and the like. The vacillating rapid flight is familiar, and in some bats the power of flight is strong enough to enable them to migrate as birds do.

The Aerial Mammals.

In relation to the bat's twilight habits, the sense of touch is highly developed on the wing, and about the nose and ears, so that obstacles



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before. The back teeth of small bats bear sharp cusps, well suited for crunching insects, and a crowning adaptation may be found in the winter sleep of the bats of northern countries.

The large bats, sometimes called "flying foxes," ranging from Madagascar to Queensland, are all fruit-eaters. The small bats are typically insect-eaters, but some are carnivorous, a few take fruit, and a few are blood-suckers. In the Vampire (*Desmodus rufus*), which feeds on blood, the gullet is so narrow that nothing but fluid could pass down. In his *Edge of the Jungle* (1921) Mr. William Beebe gives a graphic description of the vampires of British Guiana. They entered the bungalow at night and flew about, fanning the faces of the inmates, but for a time never touching. Eventually one would settle down on an exposed foot or arm, and creep on it, pushing with the feet and pulling with the thumbs, after the usual bat fashion, but so gently that the only sensation was a slight tickling and tingling. All this was preparatory to a small bite which would not awaken a sleeper.

Vampires.

British bats are all insectivorous. They congregate in considerable numbers in trees, caves, roofs, and holes in towers; but the sexes usually live apart. While typically nocturnal, they are occasionally seen in daylight; and, similarly, while they typically hibernate in winter, they are often seen if there is a spell of mild weather at that season.

§ 8

The essential quality of dwellers in the desert is a capacity for rapid movements—to find herbage in a new area, to get out of a dry and parched land, and to flee from enemies when there is no possibility of concealment. Thus it is profitable to have long legs, a strong heart, good wind, and keen senses. The fleet Antelope may serve as a type, and there is a touch of perfection in the [illegible]

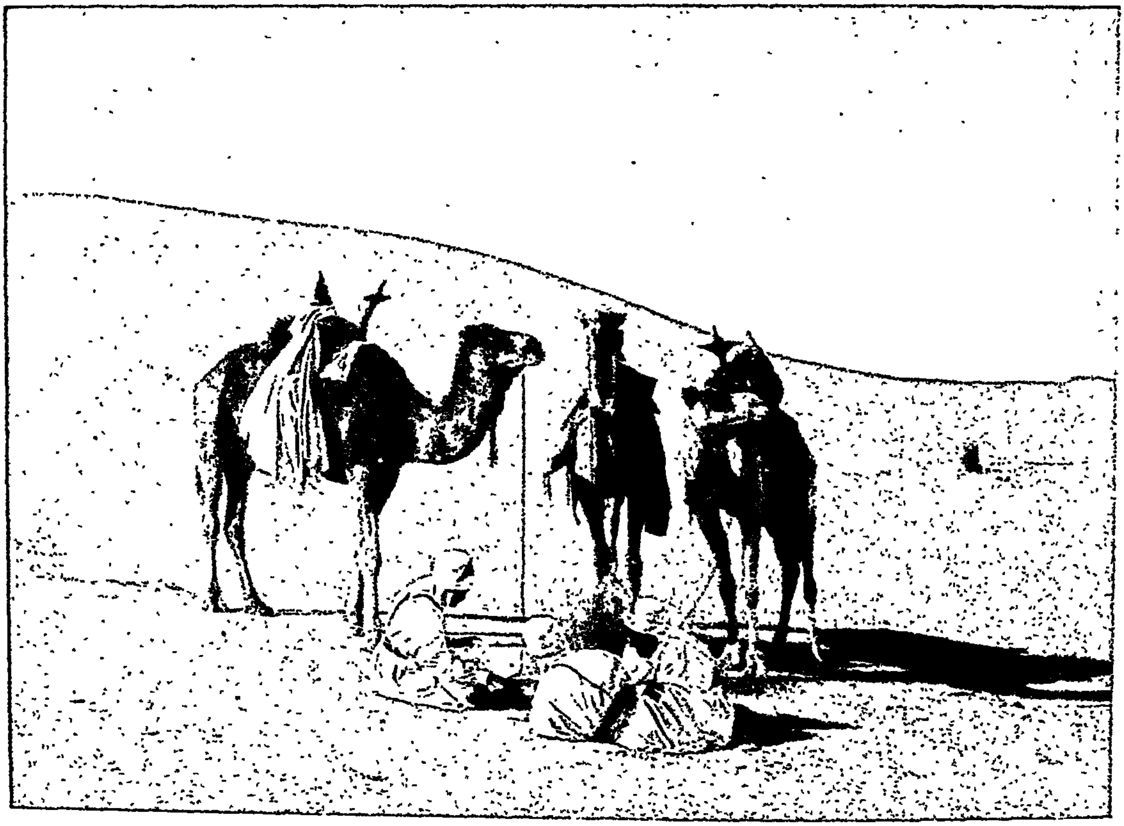
Mammals of Deserts and Steppes.

in the skeleton of the fore-limbs and in the connection of the shoulder-blade to the backbone. It is easy to interpret the reduction in the number of digits as a lessening of friction, and the same might be said in regard to the transformation of claws into hoofs, but some of the peculiarities of desert animals are not so easily explained. Are the markedly swollen nostrils of gazelles and their relatives adapted to facilitate respiration in their racing, or have they to do with filtering the air from the driven sand? Opinions seem to be very discrepant in regard to the protective value of the coloration of desert animals. A sandy-brown shade is certainly very common, and apparent exceptions, such as zebras, may admit of ready explanation. In the open the zebra can look after itself and show quick heels; in the oasis it may be that the striping is very inconspicuous. It is said that the huge giraffes are very inconspicuous in a grove of acacia-trees.

The two-humped Bactrian Camel and the one-humped Arabian Dromedary show various fitnesses for sandy deserts. Thus the two toes have short nails instead of hoofs, and are almost embedded in a strongly developed expansible sole-pad with an elastic cushion between it and the bones. The result is a surface which expands under pressure, and is well suited for moving over the loose sand. In the closely related Llamas from the Andes each toe has its own sole-pad, which is adapted for the mountain paths. Many desert animals can go for a long time without food or drink, and this is especially

THE JERBOA. (From a specimen.)

A Jerboa (Dipus), a biped mammal, adapted for life on the deserts and steppes. The ankle joint is very high off the ground; the foot has a tuft of hair which prevents it sinking into the soft sand; the tail is useful in balancing; the fore-limbs are bent close up to the neck. The length of leap is extraordinary, and the creature vanishes almost instantaneously. Jerboas are also able to burrow. An astonishing feature is the coalescence of the three instep or metatarsal bones into one, presenting a strong resemblance to the tarso-metatarsus of birds. More remarkable still is the "soldering" together of the neck vertebræ. Jerboas of this genus are confined to the Old World.



THE MIDDAY HALT.

Camels are represented to-day by the two-humped Bactrian Camel (*Camelus bactrianus*) and the one-humped Dromedary (*C. dromedarius*), and by the geographically far distant Llamas (*Lama*) of South America. Neither of the Old World forms is now known to occur in a thoroughly wild state. Herds that have gone wild or become "feral" are well known. The spreading out of the third and fourth digits is adapted for treading on soft sand. The paunch has got "water-cells" and smooth walls. A quite unique feature is that the red blood corpuscles are elliptical in contour, instead of circular as in all other mammals.

true of dromedaries. In the paunch of these animals, and in camels, there are numerous side-pockets with narrow openings which can be closed by circular muscles, and these become filled with fluid. But we must not make too much of this, for the water-pockets are also seen in the Llama. Indeed, there are traces of them in the American Peccary, which is related to the family of pigs. What has happened in the case of the Camel and Dromedary is probably that special and adaptive use has been made of what was already present apart from desert conditions altogether. More unique is the development of a hump or of two humps, consisting chiefly of fat. When the animal obtains for a time a considerable quantity of moist herbage, the hump stands up tensely; when supplies are scanty the hump is reduced in size and becomes flabby. Another adaptation may be found in the Camel's power of completely closing its nostrils during a sand-storm.

Mountain Mammals.

Really great mountains often show three zones—of forest, of steppe-land with scanty vegetation, and of barren grounds or tundra in the higher altitudes. Thus we find, among mountain mammals, forest forms like Bears and some Monkeys, steppe forms like Chamois and Yak, and tundra forms like Marmots and Snow-Voles. Many of the mountain mammals are of very hardy constitution, with thick fur, with great climbing powers, and with a capacity for enduring severe conditions and a starvation diet. Many are refugees from the low grounds, and some, like the mountain beaver, are very old-fashioned, primitive types.

The Mountain Hare.

The Variable or Mountain Hare is a first cousin of the Common Hare, and is nowadays a distinctively northern mammal. When the ice-sheet was thick over the mountains of Central Europe the Variable Hare lived in the low grounds. When

the climate became milder it had to retreat—either further north or up the mountains. It became extinct in England, but has been re-introduced with success. Compared with the Common Hare, it is smaller as a whole, and in its head, ears, hind-legs, and tail; its flesh is whiter; it is a less dainty feeder. It does not seem to have any particular home or "form," but shifts about restlessly from one hiding-place to another. When the snow is deep it is forced to descend to lower levels. In Scotland it usually turns to white in winter, all but the black tips of its ears; in Ireland there is not usually any seasonal change of colour.

The Story of the Snow-Mouse.

One of the most definitely mountain-haunting mammals is the Snow-Mouse, or, accurately, Snow-Vole (*Microtus nivalis*) of the High Alps. It is a little creature about five inches long in body and two more in tail, usually rusty-grey or whitish-grey in colour. Perhaps it has the honour of living a harder life than any other mammal, for it is rare below 4,000 feet, and it ascends from the snow-line to the tops of the mountains. It does not migrate in winter; it does not hibernate; and it does not turn white. In fact, its only adaptation to its snowy retreats is that in the summer it gathers to its nest among the loose rocks a store of chopped grass and gentian roots. In winter it makes tortuous burrows beneath the snow, mining its way from one Alpine plant to another. It has the reward of freedom from enemies, for even birds of prey are scarce at these heights. The explanation of the habitat is interesting. The snow-mouse used to be one of the "tundra" animals, like Reindeer and Arctic Fox, that frequented the low grounds of Central Europe when the uplands were covered by a great ice-sheet. As the climate became milder and the ice-sheet melted, some of the "tundra" animals, like the Reindeer and Arctic Fox, retreated northwards, but the Snow-Mouse went up the mountains, higher and higher. Thus we also understand why they have to-day a scattered distribution, separated by extensive mountainous tracts where none occur. This corresponds to some extent to separate migrations from the low grounds; it also has to do with the available vegetation, for the hardy Snow-Mouse must eat something.

§ 9

Mammals show a thousand and one adaptations connected with procuring and utilising their food, and we cannot give more than a few illustrative examples.

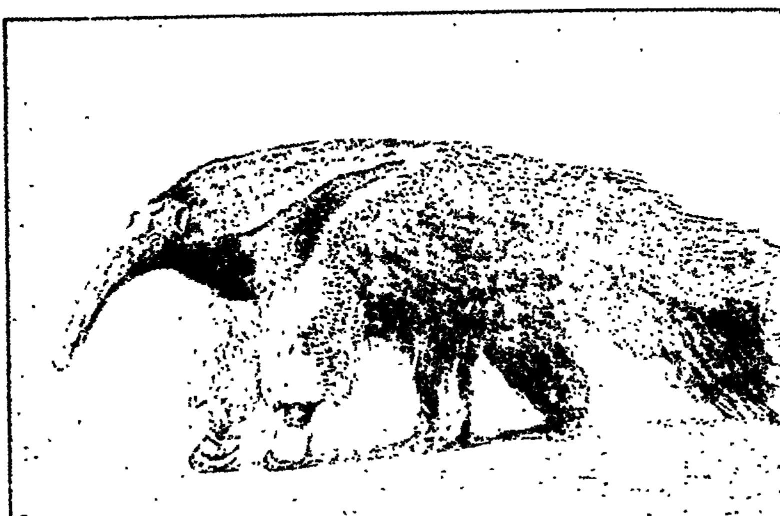


Photo: James's Press Agency.

GREAT ANT-EATER.

The Great Ant-eater (Myrmecophaga) is one of the South American terrestrial Edentates. There is no hint of teeth, but insects are caught by the rapid protrusion and retraction of a worm-like sticky tongue. The powerful claws are used in tearing up the ground or breaking into ant-hills; they are formidable weapons besides. There is shaggy greyish-black hair over the body, a broad white stripe on the shoulders, and a big bushy tail, only partly shown in the photograph. The length from the tip of the greatly elongated snout to the tip of the tail may be over 7 feet.

Food-getting among Mammals.

The Great Ant-eater (Myrmecophaga) of South America comes out at night and with its exceedingly powerful claws breaks into the earthen hills of the termites. Then out and in whips the thread-like sticky tongue, drawing hundreds of insects in a short time into the absolutely toothless mouth. The same kind of tongue is seen in other ant-eaters, such as the Aard-vark of South Africa, and in the oviparous Echidna, which is also absolutely toothless.

The whalebone whale, of whatever kind, swims

open-mouthed through the surface waters, engulfing myriads of small sea-snails and the like in the huge gaping cavern. The small animals are caught on the frayed edges of the baleen plates, exaggerated horny ridges of the palate, which hang downwards from the roof of the mouth. Every now and then the whale raises its tongue and brushes a multitude of the entangled creatures towards the back of its mouth, where they are gripped by the pharynx and swallowed. The water streams out at the sides of the mouth through the sieve of whalebone, but some of it would be apt to "go the wrong way" were it not that the whale shunts its glottis (the opening to the windpipe) forward to embrace the posterior end of the nasal passage. What a contrast is such a mouth to that of a toothed whale, like the Sperm-Whale and the Dolphin, with teeth well suited for seizing cuttlefishes and fishes! Yet it is interesting to notice that the whalebone whale has before birth two sets of teeth, which never cut the gum!

The adaptations of the teeth of mammals to different kinds of food-getting are many; but from a few we may learn all. In the gnawing mammals or rodents, such as rats, beavers, porcupines, and squirrels, the enamel is either confined to the front of the incisors, or it is much more strongly developed in front than it is behind. Thus the posterior part of the tooth wears away faster than the anterior part, so that a chisel edge is automatically formed. The lower incisors strike in behind the upper ones, and this keeps the enamel edge sharp. Moreover, these teeth are "rootless," and go on persistently growing as they are worn away. In the gap behind the incisors, where canines should be, an infolding of the skin into the mouth cavity separates a front portion from a back portion. Thus material which is being gnawed, but not intended to be swallowed, may be kept from going beyond the front region of the mouth. Some of the rodents, like the Gopher, store what they gnaw in capacious cheek-pouches, and grind this with their back teeth when they get into a place of safety.

No one can look at an elephant using its trunk without recognising a new idea—the employment of the nose (and a prolongation of the upper lip as well) as a food-getting organ. This is Nature's way, making an apparently new thing out of something very old; and it is evident from the remains of extinct elephants that the trunk or proboscis had a gradual evolution, proceeding in correlation with that of the huge tusks which prevent the mouth getting close to things in the usual way. The efficiency of the trunk is greatly increased by a very mobile, finger-like process at the tip, which enables the elephant to handle little things as well as to lift great logs.

The trunk of the Elephant is a masterpiece, and the initial stages may be discerned; not only in the evolutionary history, but in the short proboscis of the Tapir, and even in the sensitive snout of the Pig, which is used for routing in the earth in search of food. There is a special snout-bone (pre-nasal) in pig and mole; but the risk of hasty interpretation in terms of fitness may be illustrated by the fact that the same bone occurs in the Tapir, which does not rout in the earth, and also in Tree-Sloths! The bone in question is probably a primitive feature, for the Tapir, for instance, is a very archaic mammal. In some cases, like the Elephant Shrew, the proboscis is a puzzle: we do not know its use.

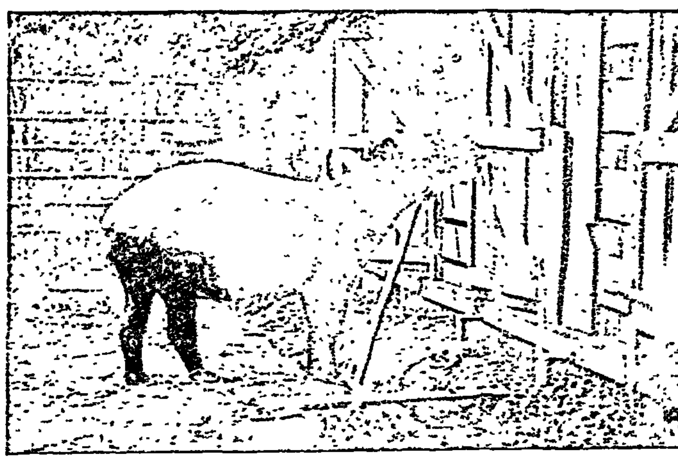
The Elephant.

The Elephant type, now represented by two species, the African and the Indian, exhibits many zoological peculiarities besides the familiar trunk and tusks. Thus the limbs are quite unique among living mammals in their straightness; they form vertical pillars adapted to support the huge weight of the body. But there is even greater interest in the ways of the creature. According to Sir Samuel Baker (*Wild Beasts and their Ways*, 1890), the African Elephant can charge for a short distance at the rate of fifteen miles an hour, and keep up the rate of ten miles an hour for a long run. The tusks which form the weapons of the males in their furious combats are used by both sexes in everyday life for digging up roots for food. It is said that an elephant does not reach proper maturity till it is forty years old, and that it may live far over a century. It is one of the slowest of breeders and carries its young for twenty-two months before birth. Yet we recall Darwin's calculation that after a period of 750 years there would be nearly nineteen million elephants alive, descended from a single pair. The cerebral hemispheres of the big brain

Photos: by courtesy of Charles Hose.

THE TAPIR OF SUMATRA (*TAPIR INDICUS*).

It will be noticed that the young one (upper photograph) is striped and spotted. These stripes disappear during the first year, giving place to a well-defined black and white pellage when fully adult (lower photograph). The young one, with its yellowish spots and stripes, is "like a patch of ground flecked with sunlight"; the adult with its two colours is like a grey boulder. Tapirs form a small family of hoofed mammals (Ungulates) related to rhinoceroses and horses. Their modern geographical distribution indicates great restriction compared with that in bygone ages, for some of the species occur in the Far East, the others in South and Central America.



are richly convoluted, and the creature is so intelligent that "elephant stories" are proverbial. Of its memory, of its capacity for learning both in peace and war, and of its practical judgment, there is no doubt.

Chewing the Cud. Some of the hoofed animals, such as cattle, sheep, and deer, illustrate an interesting peculiarity called chewing the cud, or rumination. These animals feed, as everyone knows, on grass and herbage, and it is often important for them to eat as much as they can in a short time. A choice patch must be utilised to the full, and there is always the danger of an attack from carnivores. So the ancestors of our sheep and cattle got into the habit of gorging themselves with hastily swallowed grass, and then of retiring to the place of safety—often with their backs against a rock so that they could not be surprised from behind. There, at leisure, they re-chewed their hasty meal.

The so-called stomach of a typical ruminant, such as sheep or cow, consists of four chambers. The first is the capacious paunch or rumen, the internal surface of which is thickly beset with tag-like processes, suggesting velvet pile. It is here that the grass is stored; it is acted upon by the salivary juice which has followed it down, and there is also some bacterial fermentation. The second chamber, the honeycomb bag or reticulum, is marked by a hexagonal pattern, and it rarely contains more than sappy fluid. The third chamber, the many-plies or psalterium, has numerous plaits filling up its cavity, so that the food has to pass through a kind of filter. The fourth chamber, the reed or abomasum, is the seat of gastric digestion. In fact, it is the true stomach, for the preceding three chambers turn out to be elaborations of the lower end of the gullet or œsophagus. This is known by the minute structure of their walls, for there is no confusing the non-glandular gullet region with the very glandular stomach region.

What happens in rumination? The cow, lying slightly on one side, returns boluses of food from the paunch to the mouth, where they are very thoroughly masticated and moistened with saliva. If we watch a cow we can see these boluses or rounded masses of vegetable matter travelling up the gullet with considerable rapidity. After the thorough chewing,

wart that has become very hard. The horns of cattle, sheep, and deer have a core of bone (growing from the forehead or frontal) covered by an integumentary hollow sheath of horn. In the Giraffe and the Okapi the sheath over the bony outgrowth does not turn into horn.

The Story of Antlers.

Antlers deserve a place by themselves. They are restricted to stags with the single exception of the Reindeer, where they occur in both sexes. They are not seen in the buck's first year, when there is only a small, permanent, skin-covered, bony outgrowth on the forehead, called the pedicle, which grows in girth in subsequent years. In the second year there is an extraordinarily rapid multiplication of bone-forming cells on the top of the pedicle, and a short unbranched antler is formed, which carries upwards the hot skin or "velvet." The blood-vessels in the velvet supply the food which admits of the rapid growth of the skin, and they also keep the growing antler tissue suitably warm. The materials for the growth of the antler itself are brought by internal blood-vessels from the pedicle or stalk. Branches from the fifth brain-nerve run up the velvet and make it exquisitely sensitive—an adaptation that saves the stag from knocking the still soft antlers against hard objects.

In ordinary deer the antlers are as transient as the leaves of the forest. They drop off and there is a new growth next year. The second antler has a stem and one branch or tine, and a new tine is added each successive year until the stag reaches maturity, after which the antler growth becomes irregular.

The shedding of the antlers is an extraordinary process. It is prepared for from the start by automatic arrangements which cut off the supply of blood from the velvet, obliterate the internal blood-vessels, and form at the base a soft tissue which loosens the organic connections between the dead antler and the living pedicle. The dying away of the base of the antler would be called disease in other animals; it has become mysteriously regularised in stags. The whole process is extraordinary; the growth of a fine "head," perhaps 70 lb. in weight, takes place in three months—an expensive utilisation of material called into activity by chemical messengers (hormones) from the reproductive organs. The splendid result is hardly finished before operations begin for its being shed! And after all, the antlers do not seem to be of much practical importance; they are exuberant outcrops of the male's virile constitution. Perhaps they have their counterpart in the male narwhal's spear.

The Red Deer.

Britain has lost the Reindeer and the Giant Deer, a fine creature of the ancient forests, but it still has the Red Deer (*Cervus elaphus*), which is genuinely wild in some parts of the country. It stands about four feet high at the withers, and the veteran stag has truly magnificent antlers, which are called "royal" when they have over twelve "points" or branches. The stags are very combative at the breeding season (September and October) and may be dangerous to man. They are greatly excited and roar loudly, challenging other males. In their ferocious combats they push with the antlers as a whole, or they stab at the heart and belly with the lowest branch or "brown-tine," which points forwards and upwards. A good deal of use is also made of the hoofs, especially those of the fore-feet. Each stag tries to attach to himself as many females as he can. The fawn is born in May or June, spotted as in most deer; it is carefully guarded by the mother, who teaches it to conceal itself when it hears the danger-signal—a tap with the fore-foot. In the summer months the hinds and fawns usually live apart from the stags, and often at a lower level. Although we associate the Red Deer with the Highland hills, to which they are well adapted in their strength and swiftness of limb, in their close-set coat, and in their wonderfully keen senses of smell, sight, and hearing, they were originally forest mammals rather than mountain mammals. They feed mainly on soft grass and heather shoots, but they have interesting vagaries of appetite such as gnawing at their cast-off antlers. Like the Reindeer of the Far North, they sometimes travel a long distance to get an early morning lick at the rocks on the seashore.

Protective Adaptations.

Some of the archaic mammals show a remarkable development of armour. The Armadillos are unique in having a bony skin-skeleton which is almost invulnerable, especially when the animal rolls

their survival partly to their nocturnal habits, but it cannot be said that they are in any very marked way adapted to walking in darkness.

The Badger (*Meles taxus*) has still a firm footing in various parts of Britain, such as Devon and the New Forest. It is a thick-set, round-backed, rather bear-like carnivore, somewhat over two feet in length, with an additional seven inches of tail. It has a long muzzle, well suited for its restlessly inquisitive poking into holes and corners; the short rounded ears are not in the way in the brushwood; there are bright bluish-black eyes; there is below the tail an odoriferous gland with a disagreeable smell. The Badger stands alone among British mammals in having the under parts darker than the upper, for the under surface is black while the upper surface is tawny, overlain with grey, darkening here and there. The head is practically white, divided by a broad black band beginning between the nose and the eye and extending back to the ear. In short, the colouring is rather conspicuous, recalling the American Skunk. But the Badger is elusive, and though it has few enemies it will work its way in the dusk down a dry ditch or along the side of a hedgerow rather than cross the open. The heavy body does not seem to be lifted much off the ground, the snout is often held very low, the soles of the feet are entirely on the ground in true plantigrade fashion. Yet the badger's movements have an easy swing, and the creature does not know what it is to be tired.

The Story of the Badger.

When we ask how the Badger manages to survive in a much cultivated and far from friendly country, part of the answer is in the words nocturnal and self-effacing, and, possibly, evil-smelling. We must add, however, that the Badger has strong positive qualities. It is very muscular; it has a strong heart and a good wind; the grip of the lower jaw is unsurpassed in tenacity; the thick coat helps the badger to withstand the cold of winter; it stores a good deal of fat; it is endowed with keen senses, shrewd intelligence, and a capacity for taking things easily without fuss or worry. And yet this is not all. It has an extraordinary catholicity of appetite, which always makes for survival. If one kind of food fails, it can fall back on something else—roots and fruits, nuts and truffles, worms and grubs, frogs and snakes, eggs and young rabbits, the grubs from the wasps' nest (for the badger is impervious to stings), and the honey from the humble-bees' store. Another factor is its burrowing habit, for its "earth" or "set" goes far in and may have several entrances. It is made comfortable

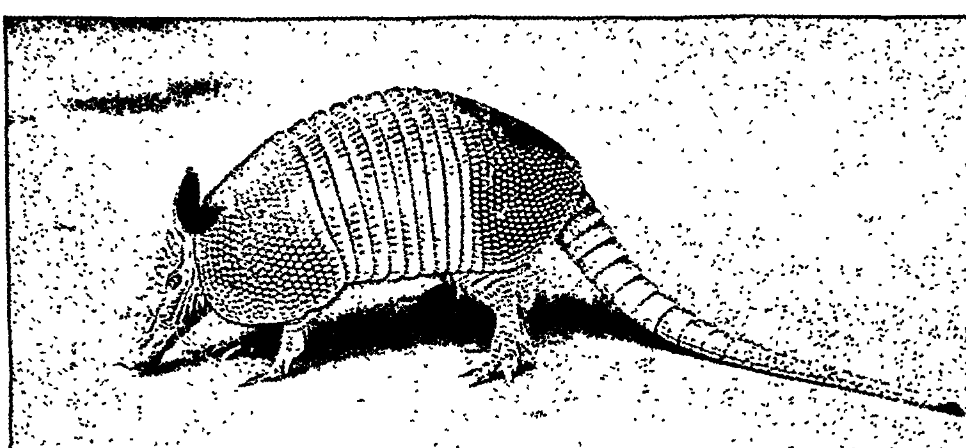


Photo: W. S. Berridge.

NINE-BANDED ARMADILLO OR PEBA.

This strange archaic type (*Tatusia novemcincta*) occurs in arid regions in South America, and extends into Texas. Between the shoulder-shield and the hip-shield there are nine movable bands, but the creature does not roll itself up into a living ball. It is only in Armadillos that plates of bone occur in the mammalian skin; above the bone there are epidermal scales of horn. The teeth are numerous small, blunt pegs, without enamel. The Peba can run quickly and burrow quickly; it uses its claws as weapons. It hunts for insects at night, or at dawn and dusk; during the day it keeps in its burrow, which may descend for 6 feet into the dry soil. Very remarkable is the fact that this Armadillo normally produces *quadruplets*—four embryos from one egg-cell—and these, as might be expected, are always of the same sex, either all male or all female.

with bracken and herbage, and is kept fairly clean. Moreover, one must attach survival value to the education which the mother badger gives to her silvery-grey cubs. There are usually just two or three of them, born in spring. When they have got their sight, some ten days after birth, and had their usual gastric education on milk, they are taken outside the warren and well groomed. Then comes schooling, and the mother is a stern disciplinarian. She punishes the inattentive and foolhardy, and gradually instructs them in the way in which they should go.

Photo: W. S. Berridge.

EUROPEAN BADGER

The Badger or Brock (*Meles taxus*) is somewhat bear-like in its thick-set body, rounded back, short ears, depressed head, and flat-footed gait. It is over two feet in length, not counting the relatively short tail. It ranges through the northern parts of Europe and Asia, and still holds its own in some parts of Britain. Its survival may be traced in part to its vigour of constitution, to its burrowing and nocturnal habits, to its catholic appetite, and to its instruction of the young. The pair live together in the "earth" which is kept clean, although the repulsive smell does not suggest this. Badgers levy a slight tax on the eggs of game-birds, but they do very little harm, and it is a pity that they should be thoughtlessly eliminated.

The Hedgehog. The Hedgehog is an old-fashioned insectivore that holds its own well from Britain to the Ural Mountains. It does so in virtue not of brains or of weapons, but because of other fitnesses. Many of the hairs have been transformed into sharp spines, which are erected by the smooth muscles at their base whenever the animal is touched. They also serve to break the force of a fall when the Hedgehog, a good climber, tumbles from a wall or a tree. A very strong dome of muscle beneath the skin (see page 354) rolls the animal up into an unopenable ball. The senses are acute; the prolonged snout is well suited for probing into holes; there is a wide range of appetite—earthworms, grubs, slugs, and small snails; and the mountain-top-like cusps on the back teeth are well suited for crunching these. The constitution is very tough, and if the Adder—an inveterate enemy of the Hedgehog—gets a bite in, the venom has no effect. Experiments with poisons and with such germs as that of diphtheria have proved the refractoriness of this common creature. Although it has few enemies, it adds to its safety by resting during the day in a well-hidden recess, and hunting by night. There are often two litters (usually of three or four) in the year, and the young one is a curious flat and feeble creature, with soft white spines pointing backwards, and a pale blue-grey skin. It is not for some time able to roll itself up, yet it develops quickly, and is able to follow the mother in a month or two.

§ 12

Hibernation. Many creatures, such as reptiles, amphibians, snails, and insects, pass into a lethargic state when winter sets in, and lie low until the spring. But it is only in mammals that we find true hibernation, a very peculiar physiological condition, which is not sleep, nor *necessarily* connected with winter. It is exhibited by Hedgehog and Hamster, Dormice and Bats, Marmot and Souslik, the Spiny Ant-eater of Australia and the Jerboa of the Kirghiz steppes.

To understand the hibernation or so-called winter sleep of these mammals, it is necessary to recall the main facts in regard to animal heat. Inside the body heat is produced by various chemical processes, but mainly by the muscles; it is of great importance in facilitating the operations of the living laboratory. But the heat tends to be lost by radiation into the outer

Photo: Aberdeen University Museum.

THE HEDGEHOG

The Hedgehog (*Erinaceus europaeus*) is an old-fashioned Insectivore, ranging from Ireland to the Ural Mountains. It survives in virtue of its nocturnal habits, its tough constitution, its armour of spines, its power of rolling itself up, and its capacity for hibernation. The spines are transformed stiffened hairs. The staple food consists of earthworms, slugs, and insects—both larval and adult; the back teeth bear mountain-top-like cusps well suited for dealing with this sort of diet. The pointed muzzle is adapted for probing into holes. The four to six young ones, born in a hedgerow nest or at the foot of a hollow tree, are at first very flat, with white soft spines pointing backwards, with a bluish skin, and without the power of rolling up.

world through the skin, and in the hot breath and in sweating. The non-conducting fur in ordinary mammals and the blubber of whales lessen the loss from the skin, as do the feathers of birds. But there is in birds and mammals a self-regulating system, which keeps the temperature approximately constant, day and night, year in and year out; and this is what is meant by warm-bloodedness. The regulating centre is in the brain, whence orders issue to the muscles, blood-vessels, and skin. If too much heat is being produced or lost, an adjustment is effected. But all mammals are not perfect as regards this heat-regulating arrangement, and it is among these that hibernation occurs. A good example may be found in the Spiny Ant-eater (Echidna), whose temperature may vary ten degrees Centigrade according to that of the outside world, whereas our temperature varies only by a fraction of a degree as long as we are in good health. Now the Spiny Ant-eater is a hibernator, and this is the clue we need: winter-sleeping mammals are imperfectly warm-blooded. When the cold weather sets in, it becomes difficult for them to adjust the debtor and creditor account as regards heat; they cannot produce enough to make up for their loss, and they give up the attempt. They sink back into a state of comparative coldness and cold-bloodedness; they relapse into the ancestral reptilian condition.

But if the imperfectly warm-blooded mammals which we have mentioned were to fall asleep in the open, their body-temperature would go down and down, and they would die. What they must do is creep into some sheltered nook or comfortably blanketed hole where the temperature soon becomes much higher than that of the world outside. To this temperature that of the sleeper's body approximates without there being any fatal results.

Along with the snuggling into a confined space, must be taken the great reduction of internal activities, and here hibernation ap-

proaches the lethargy of frog and tortoise. Income is *nil*, so expenditure must be reduced to a minimum. The heart beats feebly, the breathing movements are scarcely perceptible, the excretion or filtering which is the work of the kidneys comes to a standstill. The hibernating body is like a fire well banked up in its own ashes, and in an animal like the Hedgehog we know that subtle changes come about in the recesses of the tissues.

The gist of the matter is to be found in the three facts: (1) a constitutional imperfection in the temperature-regulating arrangements;

SKINNED HEDGEHOG.

Showing the attitude of the animal when rolled up. Very noteworthy is the great dome of muscle which contracts the animal into a living ball. It will be noticed the muzzle is bent down very nearly to the toes, and that the fingers are touching the toes.

(2) a creeping into a confined space which gets warmed up a little; and (3) a great reduction of expenditure, for even the internal activities come almost to rest. But there are some contributory influences which must be recognised. After the hard work of summer, there is naturally some fatigue and a bodily bias towards rest. Moreover, summer has often been a time of plenty, and the body has accumulated stores of fat and other reserves, which may also incline the creature to somnolence. And once the quiescence has begun, it will tend to continue, for the closeness of the retreat must be soporific, and the cessation of the kidney functions will tend to keep the sleepers sleepy. Just as drowsiness sometimes sets in when man's kidneys are not working rightly, so in the hibernating mammal there may be a poisoning of the body with its own waste-products—a sort of "auto-intoxication."

Yet this is not all. We must not think of hibernation as an individual reaction merely; it expresses a racial rhythm. In the course of thousands of generations a certain periodicity has been established, like that of our sleepiness at night and wakefulness in the morning, and with the enregistered bodily rhythm there is associated an instinct which prompts the hibernator to seek out a comfortable corner when the weariness or sleepiness sets in. For ages, it must be remembered, our hedgehogs have not known any winter. They have slept through them all, just as the migratory birds have circumvented them all. It must be remembered, too, that the winter-sleep or hibernation of an animal like the Hedgehog cannot be distinguished from the summer-sleep or æstivation of the Tenrec of Madagascar.

Only a few mammals are hibernators, and some of these, like the Dormouse, are "light sleepers," while others, like the Hedgehog, are "deep sleepers." In all cases there is some imperfection in the warm-bloodedness, and what has been wrought out is what we might call a rather neat way of making a strength out of a weakness. There is a relapse to a reptilian condition, but this handicap is counteracted. For it is not merely that the difficulties of the winter—scarcity, cold, and storms—are circumvented; the hibernation gives an opportunity for a long rest, which even the food-canal may be the better for. There may be an opportunity for processes of recuperation or rejuvenescence to stave off the processes of senescence or ageing. Why, then, are there not more hibernators? The answer must be that hibernation is the "answer-back" made by certain creatures with a constitutional peculiarity; other mammals meet the winter in other ways.

§ 13

Sex Dimorphism.

The contrasts between lion and lioness, between stag and hind, are familiar. They illustrate what is technically called sex dimorphism, i.e. a marked structural difference between male and female. The contrasted characters are called second-

ary sex characters, to distinguish them from primary sex characters, which have to do more or less directly with the reproductive function itself. The males are sometimes equipped with decorations—the manes of lion and bison, the beards of certain goats, the crests along the back of some antelopes, and the dew-laps of bulls. Or they may have weapons which are either absent in the females or represented in less exuberant development. Thus antlers are restricted to the males except in the case of the reindeer; the horns of bull and ram may be much larger than those of cow and ewe; the male narwhal has a spear-like tusk which is not developed in the female. There may also be differences in colour and in odour.

Darwin suggested that when the males fought for the possession of the females, as stags and antelopes do, the males with better weapons would prevail. As they would therefore have most success in leaving progeny, their strong qualities would gradually become racial characters; the males with poor weapons would be sifted out. In regard to sex decorations he suggested that the females would be most interested in, and would give the preference in mating to, the more handsome males, and that the race would therefore evolve in the direction of increased decorativeness. This is, in brief, Darwin's theory of sex selection, which is discussed in the article "How Darwinism stands To-day." But one point must be noticed here. If the quality of having strong weapons or of having handsome decorations is hereditarily transmissible, why does it not appear in the female as well as in the male offspring? How can it be entailed on the male offspring only? The answer must be that the quality is handed on to both sexes, but that it cannot find expression except in a male constitution. Similarly, the foundations of milk-glands are part of the inheritance of both sexes, but normally their development is restricted to the females. There are items in the inheritance of both sexes which are like seeds requiring particular kinds of soil if they are to develop. The male character of antlers or of shaggy mane requires a masculine constitution (including the presence or absence of certain hormones) if it is to develop. This leads to the view that the secondary sex characters are in their origin bound up with the primary differences of constitution implied in maleness (sperm-producing) and femaleness (egg-producing) respectively.

All theory apart, we return to the facts (1) that the male mammal is often markedly different from his mate, (2) that there are often fierce combats between rival males, and (3) that in certain cases the females seem to show a certain preference, being apparently more excited by some males than by others. It is probably the total get-up that counts rather than any individual item such as an extra long beard. The combats of rival stags are sometimes furious, and the antlers are occasionally interlocked with fatal results to both combatants. A male antelope sometimes punishes an upstart youngster so severely that the blood flows from many wounds.

Photo: Aberdeen University Museum.

THE DORMOUSE.

The Dormouse (*Muscardinus avellanarius*) is in some ways suggestive of a miniature squirrel. It climbs in the herbage and bushes; in the thicket in spring it makes a nest of grass and leaves. The tail is somewhat bushy; the eyes are relatively large. Head and body make up about 3 inches, the tail half-an-inch less; the colour is tawny brown above. The Dormouse frequents the central and southern districts of England. It accumulates fat in the summer, and is a light sleeper during the winter. If wakened too suddenly it is apt to die. If there be a second litter in autumn the young ones are said to die.

§ 14

Family Life.

Some mammals are monogamous, others polygamous, and others promiscuous. The monogamous forms include the Chimpanzee, the Tarsius Spectre, the Hedgehog, the Elephant Shrew (Rhynchocyon), the Pangolin, some antelopes

and small deer, and the Bandicoot (*Perameles obesula*). The polygamous forms include most deer and antelopes, wild cattle and horses, sea-lions and elephants. Not infrequently the males live by themselves except at the breeding season, as in the case of elephants and stags. An experienced old female leads the hinds and the young; a male in his prime leads the stags. Where the pair do not live together throughout the year, and where the care of the family devolves wholly on the mother, the terms monogamous and promiscuous have not much meaning. There is pairing rather than mating. A female mammal may pair with one male one year and with another next year, or with several in one year. But our knowledge of these matters is sadly lacking in precision. It has to be remembered that in most cases the pairing time is sharply punctuated and of short duration.

It is interesting to inquire into family life among apes. The Gibbons (Hylobates) of south-east Asia are the smallest of the anthropoid apes, rarely over three feet high. But they have disproportionately long arms, the hands touching the ground when the animal stands erect. They are fond of swinging like acrobats below the branches with their arms above their head. They can swing clear for 12–18 feet with the greatest ease, and pass from tree to tree unwearyingly. During the day they keep to the tree-tops, especially on the mountain-sides; towards evening they come cautiously "waddling" down in the open ground searching for fruit. Their voice is extraordinarily strong, especially in the males, and not unmusical. They are sociable and talkative. The Orang (*Simia satyrus*) of the forests of Borneo and Sumatra stands about four feet high and is very strongly built. It is highly intelligent, but somewhat sluggish in habit, climbing slowly, keeping to the trees except at night, when it sometimes searches on the ground for fallen fruit. It uses its arms as crutches or goes on all-fours. It makes for resting purposes a sort of platform nest of branches, but it moves on and makes another every second day or so. The male orang lives apart; but the mother keeps her family with her for some time. The Chimpanzee (*Anthropopithecus troglodytes*) of African equatorial forests may be five feet high, but it is not so bulky as the orang, and it is as good a climber as the Gibbon. It makes a temporary platform or resting-place among the branches. In disposition it is lively and playful; it is easily tamed, and has a plastic intelligence. The Gorilla, also restricted to Tropical Africa, may be a little over five feet in height, and is of enormous strength in shoulders and arms. It goes much more on the ground than any of the other anthropoids, and has a shuffling, rolling gait, using the hands a good deal, and keeping the body semi-erect. It fights ferociously with hands and teeth, and does not retreat from man. It is said to be gloomy; it beats on its breast when enraged; it has never been tamed. A single adult male usually leads a small company of females and young ones.

Care of the Young.

Some young mammals are born very helpless—blind, naked, and with little power of movement. This implies some sort of seclusion or shelter, such as a burrow or a nest, as in Fox and Squirrel respectively. In the case of the Rabbit there are both, for the mother makes a bed of her own fur. During the very helpless infancy, the mother mammal is assiduous beyond telling. In some cases, after a period of suckling, the mother brings animal food to her young ones, and that food is not always dead. For the education has to begin early. The play of the kitten (and even of the cat) with the mouse is doubtless wrapped up with the business of early education.

In some cases the young ones are carried about by the mother. Reference has already been made to the marsupials, but there are other instances. A mother hippopotamus is sometimes seen in the Nile with a calf astride on her short neck: the young are precocious, and the mothers very affectionate. Many monkeys carry their babies about with them among the branches, and so does the quaint Tarsius, which belongs to the order of Lemurs. Among bats the young one is carried by the mother as she flies, and the holding on is assisted by the front teeth, which grip the rough hairs. On a somewhat different line are the cases where the mother takes a young one in her mouth and transports it to a place of safety. This is familiar in the case of a cat and her

Photo: Royal Scottish Museum.

THE POLECAT AND ITS FAMILY.

The Polecat (*Putorius putorius*) is also known as the fichet and the foumart (i.e. foul marten, because of its fœtid odour). It is much larger than the Stoat, with looser fur, darkish all over. It lives chiefly in wooded country, feeding on rabbits and birds, but is becoming very scarce in spite of its alertness and courage. A ferret is a domesticated form of the Polecat, and is often an albino with no pigment in the hair or in the eyes (which look pink because of the blood shining through).

kittens, but the squirrel may also shift her young when danger threatens.

In some cases the instruction given by the mother is an important factor in securing the survival of the young ones, and therefore of the race. Thus the Badger instructs its offspring in the art of being elusive and in the diverse ways of securing food. Even better known is the Otter's schooling, for the young are taught all the alphabet of country sounds, how to dive without splashing, how to lie hiding under the bank without betraying themselves, how to catch frogs and skin them, how to guddle for trout and eels, how to eat the eel from the tail and the trout from the head, how to deal with rabbit and moorhen, and how to find their way home without returning on their outgoing track. No doubt there is hereditary instinctive endowment, but there is teaching as well.

§ 15

The Otter (*Lutra vulgaris*) is one of the most elusive of mammals, in great part nocturnal, shy of repeating itself or returning on its tracks, shifty in its hunting, and very thoroughly amphibious. It is much commoner in Britain than is generally supposed.

The Story of the Otter.

Part of the secret of its survival we have already referred to—namely, the training which the mother gives to her offspring, but there is more. Thus it is always an advantage to have a catholic appetite, and while the otter depends mainly on fishes, it condescends to eat the mussels and limpets on the seashore and the frogs in the marsh; and, of course, it rises to wild duck and rabbit. Another feature of survival value is the otter's nomadism. In his fine study *The Life Story of the Otter* (1915), Mr. Tregarthen calls it "the homeless hunter," "the Bedouin of the wild." It has been known to travel fifteen miles in a night, and not infrequently the holts where it lies up during the day are ten or twelve miles apart. It passes from tarn to stream, from river to shore; it swims out to an island in the sea; it explores the caves on the cliffs; it crosses the hills and hides in a cairn; it is always on the move—a gipsy among carnivores

In resourcefulness the otter is unsurpassed—lying hidden below the waterfall, wrenching a trap off under the roots of the alder-trees, diving at the flash of a gun, even hunting for pike beneath the ice of the lake. There are savage fights between two dog-otters who desire the same mate; the parents are often severely taxed to provide for the young; but the greater part of the otter's struggle for existence in Britain is in circumventing the difficulties of modern life.

The Common Hare.

The Common Hare (*Lepus europæus*) might be called a gentle Ishmaelite. Everyone's hand is against it, but it is against no one unless it be greatly roused, for instance by a stoat approaching its leverets at play. Yet it extends all over Europe, except in Ireland, the north of Scandinavia, and the north of Russia. How does it survive? It seeks resting-places or "forms" from which it gets a good look-out over the surrounding country; it has long-sighted eyes, quick ears, and keen smell; it utters a danger-call to its kin by grinding its teeth; its heart is such that it can put on full speed the moment flight is signalled; it rejoices in an uphill race; it criss-crosses its tracks so that even the astute fox is baffled; it disappears like an arrow when it is startled; and even when it is resting among the ferns and herbage, or on a ploughed field, it is almost invisible save as to its wide staring eyes. Much as it dislikes wetting its fur, which is slow to dry, it will swim across a broad river to baulk pursuit or to reach greatly appreciated dainties like musk and camomile. Epicure as it is, fond of tender corn and the sweet trefoil, of wild thyme and the seashore pea, it has a long bill of fare, which always aids in survival, and it will pass from lichens on the rocks, which its cousin the mountain-hare also eats, to the twigs of furze-bushes, and from the leaves of dandelions to the fruits of the bramble. Let us take three more illustrations of the hare's astonishing fitnesses. How simple and yet effective is its habit of taking a great leap from and into its "form" or nest, so that the scent track is interrupted. In his fine study, *The Story of the Hare*, Mr. Tregarthen notes that the doe leaves little scent when the young ones are helpless in the nest, that is, about the month of April. When a particular nest is endangered, it may be by a hungry vixen, the doe hare will transport its leverets to a safer place, carrying one at a time in her mouth, at dead of night. It is said that if the litter be over two—cases of 4–6 are recorded—there may be a division into two nests! Elusive is the word for a hare, but at the breeding season in March the instinct of self-preservation wanes before sex-passion. The bucks race about at a high speed in the open day and in the open field, searching for the does and fighting with rivals. They box with their paws and kick with their hind-legs, and a common trick is for one buck to jump over another, kicking back as he does so. The buck is a roving lover; he may consort with one doe for a little while, but he soon seeks another. The hare is a high-strung creature, with quick-beating heart, rapid breathing, tremulous ears, but it presents a brave front to persecution, now saving itself by its alertness, and again by its capacity for lying low. As there is no burrow, it is not surprising to find that the leverets are born furry and open-eyed, very different from the naked young of their second cousins, the rabbits.

The Significance of Play.

There are many playing mammals, and the work of Groos in particular has shown that the play is of great importance in the life of the creature. Kittens chase a leaf whirled by the wind; puppies indulge in a sort of sham hunt; young otters and stoats are delightfully playful, and so are humble mammals like the water-shrews, which few people know much about. Lambs have many games, and goats have more; calves and foals have their races; leverets and squirrels their frolics. One may distinguish gambols, races, games like "tig," sham hunts, sham fights, and the endless game of "experimenting" in which monkeys are pre-eminent. Miss Romanes writes of her Capuchin Monkey: "He is very fond of upsetting things, but he always takes great care that they do not fall upon himself. Thus, he will pull a chair towards him till it is almost overbalanced; then he intently fixes his eyes on the top bar of the back; and, as he sees it coming over his way, darts from underneath, and watches the fall with great delight; and similarly, with heavier things. There is a washhand stand, for example, which he has upset several times, and always

without hurting himself." This illustrates the game of experiment.

Similarly, Miss Frances Pitt records a game which two ravens in a yard used to play with a cat. One of the ravens, with a good deal of bluster, would make a frontal attack on the cat. This was met on the cat's part by the usual arching of the back and other expressions of contemptuous irritation. Meanwhile, however, the other raven approached quietly from behind and tweaked the cat's tail. Whereupon a rapid face-round, and the second phase of the game began, in which the ravens exchanged parts. There was no use in the performance; it was only a "ploy" in which the cat had its share.

What is the biological significance of the play of young mammals? It has been said that play is a good safety-valve for overflowing energy and exuberant spirits; it has been pointed out that motion is linked in a subtle way to emotion, and that pleased feelings naturally find expression in pleasant movements; it has been suggested that the playing period affords opportunity for trying new ways or exercising new gifts before the responsibilities of life become too stringent. There is good sense in each of these suggestions, but the most important idea is that the play period is the time for educating powers which are useful in after life. Play is the young form of work—a rehearsal without too great responsibilities, when mistakes can be made without too severe punishment. As Dr. Groos says, playing animals do not simply play because they are young; they continue young in order that they may play. In the course of ages playing instincts have been established in many mammals, and they make for success.

The Story of the Weasel.

The Weasel (*Putorius vulgaris*) is one of the northern mammals common to Europe, Asia, and North America. It is a first cousin to the Stoat or Ermine, and an embodiment of virility. The spare sinuous body and the long neck suggest the snake, and the convergence simply means that the Weasel is adapted, like a snake, to making its way through narrow passages. The Weasel,

Photo: Riley Fortune, Harrogate.

THE OTTER (*LUTRA VULGARIS*).

This member of the Bear tribe of Carnivores is about 2 feet long, with 16 inches more to the strong tail—which helps in swimming. The fur is thick and soft, deep brown above. The claws are of use in burrowing, but the hands and feet are likewise webbed for swimming. In its present geographical distribution the Common Otter extends from Ireland to India. It holds its own in virtue of strength, strong claws and teeth, keen senses, alert wits, roving habits, versatility of diet and hunting-grounds, resourcefulness when hard pressed, ability to lie for a long time hidden under a bank, and careful education of the young.

succeeds in virtue of a nimble brain, very keen senses, highly developed muscularity without any "spare flesh," and solicitous maternal care; but it would be unscientific to overlook its extraordinary courage. It will face up to a terrier, even to a man. It will leap up and catch a partridge already on the wing. "A pair will stand affectionately and nobly by each other in danger, and a weasel mother will defend her young to the last gasp." A weasel will explore a house and defy the house-cat; it will bluff a

Photo: From Royal Scottish Museum.

VIXEN AND HER PLAYFUL CUBS.

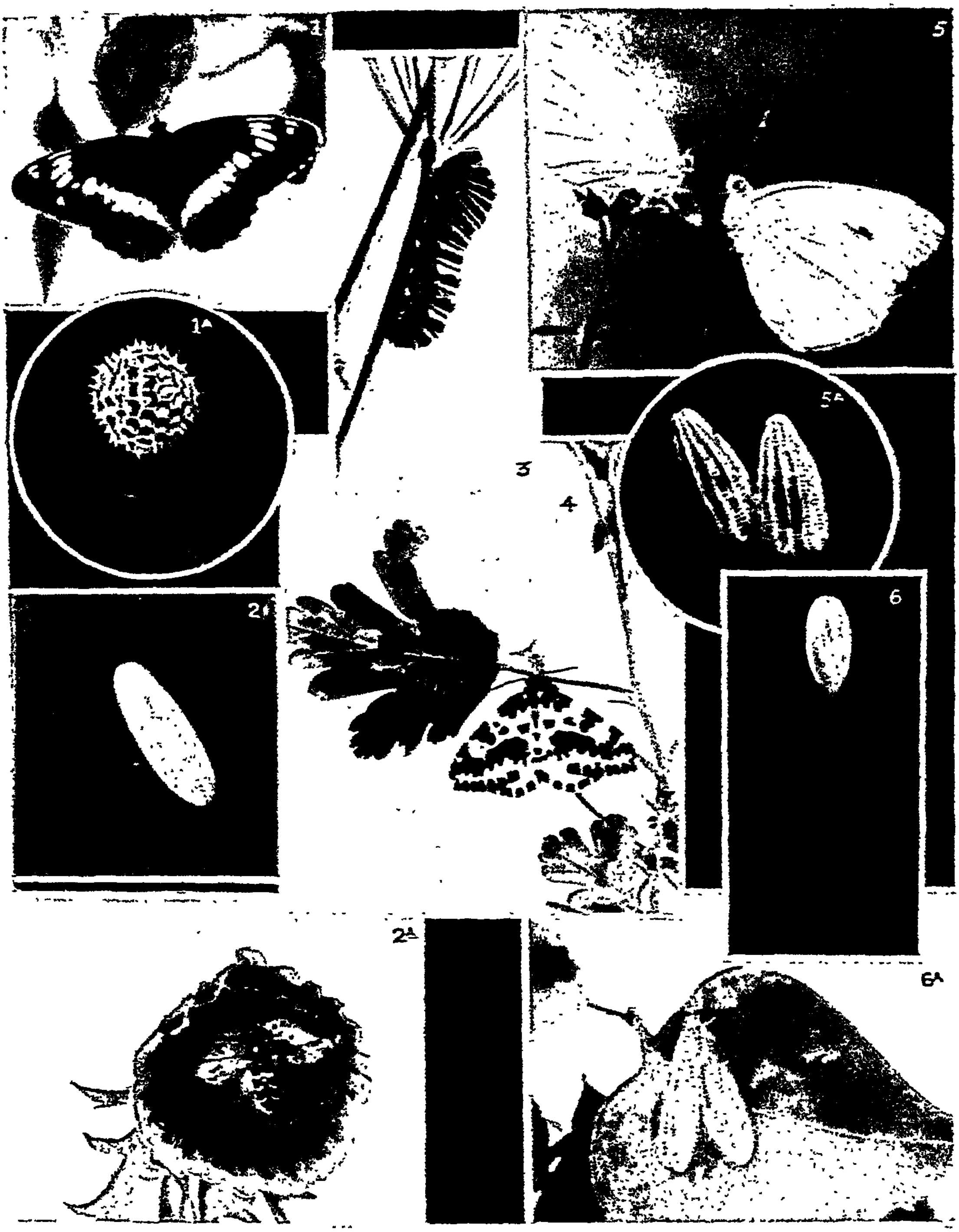
The Fox (*Canis vulpes*) is the only wild member of the Dog tribe of Carnivores now left in Britain. There is considerable variation in size and colour in different parts of the country. Foxes associate in pairs, and the four to seven cubs remain for a considerable time under the care and tuition of the vixen. The young ones are very playful and enterprising. Foxes make "earths" or burrows in hills and woodsides, and most of the day is spent in hiding. They come out at dusk, and hunt for small mammals and birds, and a variety of creatures of lower degree—down to shellfish on the shore.

lot of roosting hens that could have pecked it to pieces; whining and daring, snarling and bristling, it will retrieve its young ones from under the feet of man.

§ 16

Social Mammals.

Many mammals are gregarious and some go a step further and illustrate some measure of communal or corporate life. It is difficult to draw any hard-and-fast line. Gregariousness is illustrated by cattle, deer, wild horses, rabbits, kangaroos, and many more. The chief advantage is in the strength that numbers give against an enemy. The members of the vegetarian herd trample the carnivore to death. A small monkey attacked by an eagle has no chance, but his cries bring a crowd of comrades to his aid, and they may tear the bird of prey to pieces. Moreover, when there is a herd, there is the possibility of having sentinels or outposts, which warn the main body when danger draws near. The Rabbit knocks loudly on the ground with its feet and the Marmot whistles "danger." Whenever there is division of labour there is a sounding of the social note. Thus when baboons are retreating the rear-guard is formed by the old males, and Brehm tells the fine story of the way in which they faced the dogs of his hunting party and kept them at bay while the females retreated. "But one little monkey about half a year old had been left behind. It shrieked loudly as the dogs rushed towards it, but succeeded in gaining the top of a rock before they had arrived. Our dogs placed themselves



INSECT LIFE

1, White Admiral Butterfly (*Limenitis sibylla*) and, 1A, its egg (magnified 25 diameters); 2A, Hover Fly (*Catabomba pyrastri*) on Poppy flower and, 2, its egg (magnified 30 diameters); 3, Full-fed larva of the Swallow-tail Butterfly (*Papilio machaon*); 4, the Magpie or Currant Moth (*Abraxas grossulariata*) just emerged from its pupa skin—shown on the leaf; 5, Large White Butterflies (*Pieris brassicae*) love-making, and 5A, eggs of the Large White Butterfly (magnified 25 diameters), which are deposited on plants of the cabbage family; 6A, the Lacewing Fly (*Chrysopa vulgaris*) and 6, one of its stalked eggs (magnified 9 diameters).

cleverly, so as to cut off its retreat, and we hoped that we might be able to catch it. But that was not to be. Proudly and with dignity, without hurrying in the least, or paying any heed to us, an old male stepped down from the security of the rocks towards the hard-pressed little one, walked towards the dogs without betraying the slightest fear, held them in check with glances, gestures, and quite intelligible sounds, slowly climbed the rock, picked up the baby-monkey, and retreated with it, before we could reach the spot, and without the visibly disconcerted dogs making the slightest attempt to prevent him. While the patriarch of the troop performed this brave and self-sacrificing deed, the other members, densely crowded on the cliff, uttered sounds which I had never before heard from baboons. Old and young, males and females, roared, screeched, snarled, and bellowed all together, so that one would have thought they were struggling with leopards or other dangerous beasts. I learned later that this was the baboons' battle-cry; it was intended obviously to intimidate us and the dogs, possibly also to encourage the brave old giant, who was running into such evident danger before their eyes."

The Story of the Beaver.

The Beaver is an aquatic mammal of a very different type, suited for rivers traversing wooded country. It is a thick-furred, plump creature, about 2½ feet long, with a flat, trowel-like scaly tail. It swims well with its webbed hind-feet and broad tail; it can remain about two minutes under water; it feeds mainly on bark. Its simplest home is a burrow with an entrance under water, but above the burrow there may be a surface pile of sticks, and from this rough-and-ready shelter there are gradations leading to a well-formed "beaver lodge" of sticks and grass, moss and mud. This includes a comfortable central chamber, with a "wood entrance" and a "beaver entrance." But the architecture varies with individuals and with the severity of

Photo: W. S. Berridge.

HIPPOPOTAMUS.

The Common Hippopotamus (*H. amphibius*) of Africa is one of the modern giants (4 tons in weight, 14 feet long), but there is a dwarf species in Liberia. Their nearest relatives are the Pigs. The huge creature can swim with efficiency, and occasionally "puts out to sea"; it can also walk along the bed of the river, remaining immersed for ten minutes. It is vegetarian. The body is almost hairless. The nostrils are situated high up, as is suitable in an aquatic creature. There is a strange bloody sweat. The hippopotamus is the Behemôth of the Book of Job—"the chief of the ways of God."

the conditions of life. With more leisure, there is more art.

Beavers can cut down trees 10 inches in diameter; they use their chisel-edged incisor teeth, covered in front with orange-coloured enamel, to split off flakes of wood all round the base of the stem, but more towards the side nearer the water. The wind then brings the tree down, and the beaver's object is attained, namely, getting at the more palatable wood on the younger branches. These are cut into suitable lengths and stored in or near the lodge. The barked pieces may be added to the building. There is no doubt that beavers make dams of brushwood, stones, and mud, thereby securing a larger area for their wood-cutting and easier conditions of transport. It is likely enough that some of the dams were started naturally by floods which carried lodges and stores away and deposited them in shallow water; indeed, we can see the beginning of such a dam in many a river in wooded country. But the point is that the beavers strengthen, elaborate, and regulate what the river itself may have begun.

Even more remarkable is the digging of canals, by which the transport of the cut branches is made easier. They may be hundreds of feet long, and they are often about a yard broad and deep. They usually communicate between clumps of trees and the pond above the dam, but they may form a short cut between two loops of the river, or they may go right through an island. In the last case the work would not be justified until there was an open waterway from end to end. In some other cases a moist roadway between the pond and a pool in the wood might be gradually converted into a canal. Instances of "locks" have been recorded, but there is a tendency to forget that animals are more likely to take advantage of what exists or is hinted at in Nature than to discover new ideas or principles!

Beavers are notably gregarious, for there may be many lodges near a suitable wood. When there is overcrowding a migration occurs, the old houses being left to related new couples. Isolated males are often found, and some naturalists say that these have been expelled from the community for lazinessormisbehaviour. There are no beavers left in Britain, but they flourish in Russia, in Siberia, and in Canada and other parts of North America. It is interesting to notice that in many places from which beavers have been gone for centuries, evidences of their work remain as "beaver-meadows" and the like.

Mutual Aid.

Prince Kropotkin did a notable service in his book *Mutual Aid, a Factor in Evolution* (1904), for he showed in a scholarly way the frequency of gregariousness, combination, co-operation, and sociality among animals. One answer-back that pays in the struggle for existence is to sharpen teeth and claws, i.e. to intensify competition; but another successful answer-back is to practise mutual aid. Even the individualistic carnivores may form packs as in the case of wolves and jackals; but there is more elaboration among the grazing herds. All kinds of beasts and birds of prey have proved powerless against the colonies of Russian sousliks. Combination gives strength to the sociable musk-rats of North America and to the prairie-dogs. "As far as the eye can embrace the prairie, it sees heaps of earth, and on each of them a prairie-dog stands, engaged in a lively conversation with its neighbours by means of short barkings. As soon as the approach of man is signalled, all plunge in a moment into their dwellings; all have disappeared as by enchantment. But if the danger is over, the little creatures soon reappear. Whole families come out of their galleries and indulge in play. The young ones scratch one another, they worry one another, and display their gracefulness while standing upright, and in the meantime the old ones keep watch. They go calling on one another, and the beaten footpaths which connect all their heaps testify to the frequency of their visits." As Darwin said, "the individuals which took the greatest pleasure in society would best escape various dangers; while those that cared least for their comrades and lived solitary, would perish in greater numbers." In short, the line of mutual aid is a trend of evolution, which has borne its finest fruits in mankind.

§ 17

Variety among Mammals.

We see the March hares racing over the ploughed field, and the sloths creeping cautiously along the under side of the branches. The porpoises gambol in the sea, and the bats with erratic flight hawk insects in the air. The mole works its

way for the most part underground, and the squirrel leaps adventurously from tree to tree. Whales are mammals of the open sea, and sometimes descend to great depths; monkeys are largely arboreal; antelopes are suited for the plains and the hippopotamus for the rivers. Wild cattle are gregarious, beavers are social, the sea-lion has his harem, the polar bear is solitary. We watch seals resting among the shore rocks, and bats hanging upside down from the rafters. In the winter the wolves join in packs, the stoat turns into the white ermine, the hedgehog sinks into hibernation. There are herbivores, insectivores, carnivores, specialists like the ant-eaters and the fish-eating seals, and others with a catholicity of appetite like badger and otter. A harvest-mouse only weighs about a halfpenny, an elephant's tusk may weigh 188 pounds. The Pigmy Shrew has a body under 2 inches in length, a whale may attain to 60 feet. A common shrew seems often to die in the year of its birth; an elephant may be more than a centenarian. But we need not go further; it is plain that there is extraordinary variety among mammals. This raises the question, what have they all in common?

General Characters of Mammals.

Mammals are quadrupeds, except that the whales and sea-cows have lost all but vestiges of the hind-limbs, and perhaps another saving clause should be inserted for kangaroos, jerboas, and higher apes, which are more or less bipeds. In most mammals there is a distinct neck and a distinct tail, but the neck is practically obliterated in whales, and the tail is often much reduced (as in bear and rabbit) or practically absent (as in the higher apes).

Hairs are never entirely absent, for even in whales they are present in early stages of life and some, very richly innervated, often persist on the lips. The mammalian skin shows sweat-glands which get rid of surplus water and some waste-products, sebaceous glands which keep the fur sleek (absent in whales), and milk-glands which are normally functional in the females only.

In mammals only is there developed a midriff or diaphragm—a muscular sheet separating the chest cavity (containing heart and lungs) from the abdominal cavity (containing the stomach and other viscera). This midriff falls and rises in the breathing movements, and is of great importance in increasing and then decreasing the chest cavity, and thus helping the entrance and exit of air from the lungs.

Mammals have many skeletal peculiarities which separate them off from all other backboned animals. The vertebræ (backbone-bodies) and the long bones have terminal caps which ossify apart from the main part of the bone; the surfaces of the vertebræ are usually flat or gently rounded; with four exceptions there are seven neck vertebræ—whether it be in the long straight neck of the giraffe or the compressed inconspicuous neck of the whale; the lower jaw is one bone on each side and works on a bone of the skull called the squamosal; the skull moves by two knobs (or condyles) on the first vertebra, whereas birds and reptiles have only one condyle; the drum of the ear is connected with the internal organ

Photo: Douglas English.

HARVEST-MOUSE ON THISTLE.

The Harvest-Mouse (*Mus minutus*) is, next to the Pigmy Shrew, the smallest of British mammals, weighing only about *one-fifth* of an ounce. It can run up a stem of wheat, and in its descent it uses its tail in a monkeyish fashion. A nest of coarse grass, with a side entrance, is built between three or four stalks of corn, and there five to nine young ones are born—blind and helpless, but developing rapidly.

of hearing by a beautiful chain of three small bones—the hammer, the anvil, and the stirrup—by which the vibrations are conveyed inwards; there is a complete bony palate separating the mouth-cavity from the nasal passage above; almost without exception there are two sets of teeth in sockets; except in the oviparous mammals the bone of the shoulder-girdle called the coracoid, which is very strongly developed in flying birds and in reptiles, is represented merely by a small process of the shoulder-blade or scapula.

The cerebral hemispheres of the fore-brain are much more developed than in other vertebrates, and their surface is very generally covered with convolutions (see figure on p. 112). The heart is four-chambered; the temperature of the blood remains in most cases practically constant; the red blood-cells are circular discs (except in camels, where they are elliptical in outline as in other Vertebrates), and the nucleus of the mammalian red blood corpuscle disappears as the corpuscle develops; the lungs lie freely in the chest cavity (they are fixed in birds), and inspiration is the active process (the opposite in birds); the vocal cords are at the top of the windpipe (at the foot in birds); the egg-cells are very small except in the egg-laying forms, and, with the same exception, the young are born viviparously, i.e. as living well-formed young ones, which are for a while nourished on milk. This enumeration of salient characters is indispensable if we are to understand how this class of Mammals stands apart from the other great classes of backboned animals, namely, Birds, Reptiles, Amphibians, and Fishes. Aristotle knew that a whale is not a fish; unless we understand the general features of mammals we will not appreciate his insight.

The dominantly successful orders of present-day mammals are (1) the Carnivores (cats, dogs, bears, seals, etc.); (2) the hoofed Ungulates (horses, tapirs, rhinoceros, cattle, pigs, hippopotamus, camels, perhaps also including the elephants); and (3) the monkeys and apes or Primates. These represent three great lines of evolution. On the Carnivore line the premium is on teeth and claws, quick senses and alert movements. On the Ungulate line the premium is on swiftness, on the power of covering long distances in search of herbage, and on such weapons as horns and hoofs, rendered more effective still when their possessors are gregarious. On the Primate line the premium is on the power of climbing, the emancipated hand, and the restless brain. Below the level of true Primates are the Lemurs, or half-monkeys—ghost-like nocturnal creatures, mostly confined to the forests of Africa and Madagascar.

Orders of Mammals.

Not very far off the Carnivore line of evolution, but much more primitive, is that of the Insectivores (e.g. moles, hedgehogs, and shrews); and the Bats with their power of flight must be regarded as the specialised descendants of arboreal Insectivora.

Balancing the Insectivores there is the somewhat humble order of Rodents, on a quite different evolutionary tack, the rats and mice, squirrels and porcupines, rabbits and hares. The toothed Whales and baleen Whales are mammals that have taken secondarily to marine life, and are as specialised for swimming and diving as bats are for flight. And besides these well-known orders, there are the sea-cows or Sirenians (including nowadays two genera only, the dugong and the manatee), the old-fashioned Edentates (sloths and armadillos, ant-eaters and pangolins), perhaps to some extent survivors of the archaic mammals. But more primitive in their affinities than all these are the Marsupials (mostly confined to Australia); and lowest of all are the egg-laying Monotremes, also Australasian.

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XIV
NATURAL HISTORY

III. THE INSECT WORLD

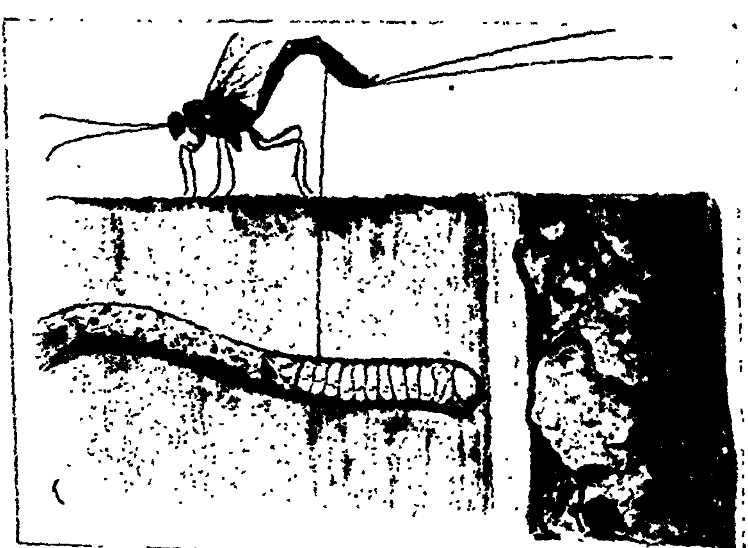
THE immense and varied group of Insects constitutes by far the largest class in the Animal Kingdom; it numbers as many as 200,000 named species, the majority of which are predominantly active types. Such a wealth of forms—the species in a single family of insects may outnumber the stars one can count on a clear night—shows that, as a class, Insects are extraordinarily successful. Many reasons are given for this dominance, all pointing to the striking fact that insects, by means of manifold adaptations, are able to fill many niches, and so attain a wide distribution. Few haunts are destitute of insect life. Butterflies and mosquitoes are known to penetrate to extreme Arctic regions; a small kind of butterfly is found in Ecuador at an elevation of 16,500 feet; insects inhabit desert tracts far out of reach of water; and limestone caverns have their cave-dwellers, often pale and blind unless their descent to this unusual haunt has been comparatively recent.

Insects almost Ubiquitous.

Many forms live in fresh water; even hot-springs have their insects, and some beetles, for instance, are found on the tidal zone of the sea-shore. The actual sea seems very unsuitable for insect life, and yet there is a family of Skimmers (Halobatidæ) which run about on the surface of the open ocean, and even dive when it is stormy.

Insects are typically winged creatures, and their power of flight extends their range, giving the opportunity to colonise new areas and to migrate to fresh localities in times of stress. Their bodies are extremely well adapted from the mechanical point of view; their sense-organs are highly developed—sensitive feelers, compound eyes, and so on—and their mouth-parts are remarkably adapted to suit different modes of feeding. Probably much of their success in the struggle for existence is due to the adaptations of their circulatory and respiratory systems, which enable the nutrition of the organs of the body to go on with great rapidity. The tissues are continually bathed in nutritive fluid, while every part of the body is kept aerated by the extensive system of air-tubes. These facts account for the abundant energy and consequent activity which is so characteristic of the class. It may be doubted if the insect's blood ever becomes impure. Another factor tending towards success is the change of habit due to the change of form which occurs during the course of many life-histories. This implies changes in diet, and therefore a lessening of the drain on any particular food-stuff. In other

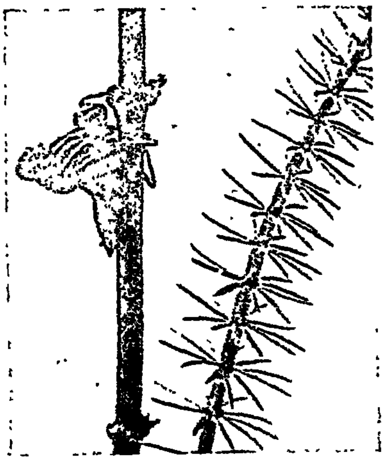
The Success of Insects.



THE FEMALE OF AN ICHNEUMON-FLY (*RHYSSA PERSUASORIA*) BORING WITH ITS OVIPOSITOR IN A FELLED TREE AND LAYING ITS EGGS IN THE GRUB OF THE GIANT SAW-FLY (*SIREX GIGAS*), WHICH IS DEEPLY EMBEDDED IN THE WOOD.

The eggs of the Ichneumon-fly hatch inside the grub of the Saw-fly, which is then devoured by the Ichneumon grubs.

THE LIFE-STORY OF THE DRAGON-FLY.



Photos: J. J. Ward.

FIG. 1. — Dragon-fly (*Libellula depressa*) emerging from its nymph skin. "Nymph" is the name given to the immature stage of insects whose life-history shows *incomplete* metamorphosis. There is no pupa. The adult stage is reached at the final moulting of the nymph skin. (See illustrations Nos. 2 to 6.)

ways, also, the changes of form and habit may lead to survival in the struggle for life, for there is frequently a tiding over of difficult times; for instance, quiescence during periods when conditions of temperature and food are unfavourable. Many insects pass the winter in a lethargic state inside well-protected cocoons.

Protective Adaptations.

Another factor which helps to give success to insects in maintaining their hold in various habitats is the way in which general form and colour are adapted to the environment. Protective colouring in animals has formed the subject of a special article, but it may be noted that there are no clearer instances of *protective resemblance* than among insects. Not only do they very often closely resemble the general colour of their natural surroundings, but form, as well as colour, may add still more to this similarity, which gives security to the insect by concealing it effectively from its enemies. We can thoroughly understand the wonder of this protective resemblance only when we study it under natural conditions; many very gaudy butterflies can hardly be distinguished from flowers when they alight on plants. Many moths in their resting position hide the bright colours of the hind pair of wings with the duller fore-wings, which may nearly resemble lichen or the bark of trees.

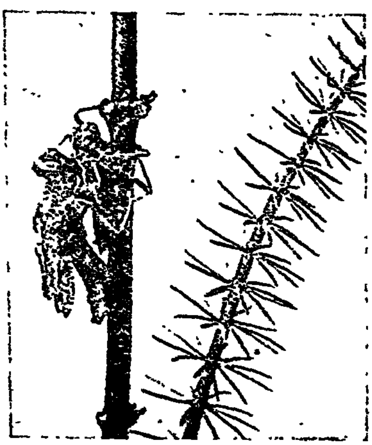


FIG. 3.—A moment later it has extricated its tail end and is free. Its wings then commence to extend from their folds. (See next page.)

The coloration may afford an effective protection in other ways, by Warning and by Mimicry. Some insects, such as the Wasp or the Lady-Bird beetle, positively court attention with their vivid colouring and markings; they are coloured, not to be hidden, but to be seen. Such insects always have some other form of protection, a sting or an unpleasant taste, which their enemies come to associate with their striking hues and therefore avoid. No doubt conspicuous individuals will be snapped at and killed while birds and other enemies are experimenting, but the enemies learn by experience, and the species with the warning colours gradually attains a position of security.

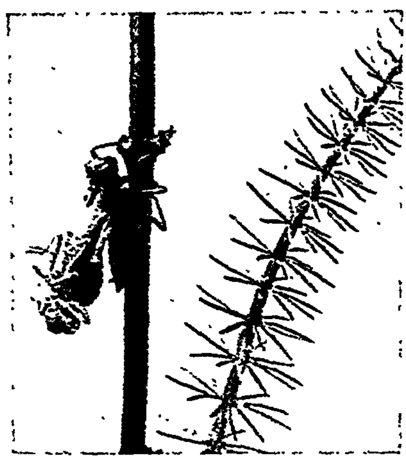


FIG. 2.—At the end of three minutes the Dragon-fly is free, all but the tip of its abdomen.

§ 1

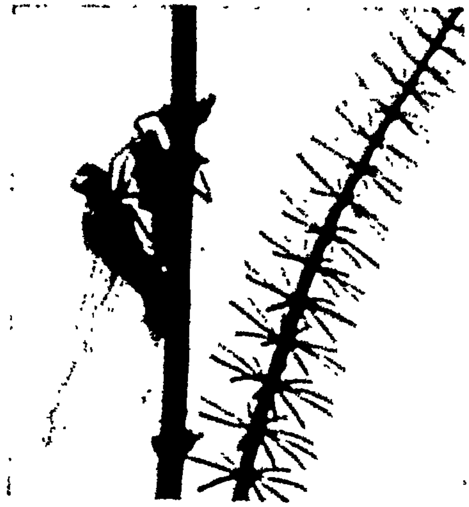
Pedigree.

The pedigree of Insects is obscure. They belong to the large group of the jointed-legged Arthropods, which shows numerous affinities with the ringed worms or Annelids, but also many advances such as the greater development of appendages. In Peripatus and its allies, which are widely distributed over the world, worm-like, velvet-skinned little creatures, shy and nocturnal in habit, we find living links between Annelids and Insects. In their excretory tubes, muscular arrangement, and hollow appendages they

strongly suggest the ringed-worm type, but they combine with these and other Annelid features distinct indications of Arthropod characters, such as the system of breathing tubes and the appendages in the service of the mouth, which reach fuller development in the class of Insects.

General Characters of Insects.

Insects, Peripatus, Centipedes, and Millipedes have in common a respiratory system consisting of tubular tracheæ, which marks them off from the gill-breathing Arthropods (Crustaceans), and sensitive feelers, which distinguish them from the Spider and Scorpion group (Arachnids). In the class of Insects the body in the adult state is divided into three main regions: (1) the head; (2) the thorax or fore-body; (3) the abdomen or hind-body.



[illegible]

Fig. 5.—After the wings have dried and come under muscular control, the insect raises itself and brings them into the natural resting attitude, as shown in Fig. 6.

The outer covering of most insects is hard and firm, composed of a non-living cuticle made of chitin, a somewhat horn-like substance secreted by the underlying living skin. The chitinous plates, which make a protective armour, are firmly fused in the head region, but in the thorax and in the abdominal part the different rings are joined by flexible areas, permitting more freedom of movement. Thus the segmented architecture of the body is more clearly seen in the thorax and abdomen than in the head region, where fusion has obliterated the boundaries of the successive segments of the body. In rapidly flying insects there is often a fusion of thorax rings to form a firm basis for the action of the wings.

It must be clearly understood that in the insect's body the muscles are *inside the skeleton*, whereas in ourselves the skeleton is covered by the muscles. The two plans of architecture are utterly different.

The Insect's Head.

The insect's head, which bears one pair of feelers or antennæ and usually three pairs of jaws, is relatively small, firm, and compact, separated from the thorax by a narrow membranous neck allowing freedom of movement. One sees this very well on a common house-fly. All adult insects (except some primitive and some degenerate species) have a pair of compound eyes, though simple eyes may be present also. The compound eyes project on each side of the head as convex, immovable structures. There

Fig. 6.—Short-bodied Dragon-fly just expanding its wings after emergence from the nymph skin which is seen near its head.

is only one pair, though each eye may be partially divided, as in some of the aquatic Whirligig Beetles in which half of the eye is directed up to keep a look-out for danger from above, while the other half is scanning the water below in search of prey. The compound eye consists of a great many similar parts—each a complete organ of vision but requiring the surrounding elements to form the whole image. Each of the many elements of the eye makes a small image, so that the whole image is a mosaic of separate contributions, which combine in a unified visual impression conveyed to the brain. For the amorous insect does not see 1,000 desired mates, —one through each of its eye-elements. The question is not an easy one, but it should be noticed that, in some cases, e.g., fireflies, the eye-elements no longer act separately, but a single combined image is thrown on the back of the eye. (See figures, pp. 230, 231.)

The antennæ are appendages set in sockets on the crown of the head, and consist of a series of joints, varying from one or two to a large number, and of many different shapes. They are of the greatest importance to the insect as organs of touch, by means of sensory bristles connected with underlying nerve-fibres, and also in connection with the sense of smell. Of hearing, in insects, very little is securely known. Further, the head carries three pairs of mouth-appendages (homologous with legs), which are variously transformed for different modes of feeding, biting, or sucking. It is very interesting to find that the same three parts are changed in scores of different ways.

Insects' Legs.

The legs, which are borne on the three rings or segments of the thorax region, show many different peculiarities to suit different habits. The front pair is considerably lengthened in certain beetles that climb about the bark of trees; in the Mole Cricket they are converted into burrowing implements, the terminal joints being arranged as shears for cutting through plant roots (see figure, p. 236). The "Praying Mantis" and the Water-Scorpion both show the fore-legs modified into pincer-like traps for seizing prey. Usually the middle pair is not greatly modified, but in some water-bugs, like the Water-boatman, the middle legs are the longest and have become effective oars for rowing on the surface of the water. The hind pair of legs of many insects is elongated for jumping, as in grasshoppers and locusts and some beetles. Certain beetles and bees and wasps have a "comb" or bristle-lined cavity on the leg by means of which they clean their feelers, while some butterflies use their feeble front legs to brush off dust from their heads. Ants are particular about their toilet. In the course of the day's work an ant's antennæ may become soiled. On its first pair of legs it is provided with what we may call brushes and combs, as we have described, and the ant may be seen to draw its besmeared antennæ through this brush-and-comb arrangement on the fore-legs. One of the legs will be passed over its head and body, its other legs sweeping off every particle of "dirt." No cat is more fastidious over its toilet. Ants will even wash and brush each other, just as they will exchange greetings, as they meet, by movements of their antennæ. The hind-legs of bees show a modification for pollen-gathering, a broadening of the "shin" to make a "basket," into which the pollen is swept by special bristles.

Insect's Breathing.

Breathing takes place by means of a system of air-tubes or tracheæ which penetrate to every hole and corner of the body. Tracheæ arise as inpushings of the skin, and the layer of chitin which lines them is continuous with that which covers the whole body. In the larger air-tubes this chitin is thickened spirally in threads, and this keeps the tubes from collapsing. Air enters the body by openings (spiracles or stigmata) occurring on most of the body-rings.

Through these spiracles the air is driven out by movements of contraction; fresh air passes in passively as the body expands. As in birds, so in insects, expiration is the active part of the breathing process. The air-tubes fork and re-fork, sending side-branches to every corner of the body, even to the tips of the feelers, so that the whole body is thoroughly aerated. The extensiveness of the air-tube system compensates for the relatively poor blood-system. In aquatic forms various devices are adopted to secure a supply of oxygen. Some water-insects come to the surface to breathe, others, like young may-flies, have special structures—tracheal gills—of different types. The Water-

Photo: J. J. Ward.

THE CATERPILLAR LARVA (SECOND STAGE OF LIFE-HISTORY) OF THE DEATH'S-HEAD HAWK-MOTH. THE CATERPILLAR IS FEEDING ON POTATO FIELD.

Beetle (Dytiscus) has its spiracles on its back, and when it dives under water it carries with it, in an air-tight compartment between its back and its hard wing-covers, enough air to last for several minutes. The bubble-of-air method is another plan, adopted by Whirligig Beetles and some water-bugs, whose covering of fine hairs entraps bubbles of air, ensuring a sufficient supply of air about the body for a short time under water.

In addition to the respiratory system there are inside the body of the insect all the usual organs—food-canal and associated parts, a heart, excretory organs, reproductive organs, and so on. Some insects are so small that they can creep through the eye of a needle, and it is difficult to believe that in such minute dimensions all the ordinary organs are packed away.

Insects are essentially active, and they exhibit various kinds of locomotion. Many grubs and maggots are quite passive, but even limbless larvæ, though naturally not so active as the legged types, have their ways of getting about. They may jerk themselves along with the aid of bristles or jaws,

Locomotion.

they may make relatively enormous leaps into the air by taking their tails in their mouths and suddenly letting go, or they may swing themselves from place to place by paying out silken lines from their mouths. Young dragon-flies propel themselves through the water by means of the forcible expulsion of water from the end of the food-canal. Insects walk, run, and jump with the quadrupeds, fly with the birds, glide with the serpents, and swim with the fishes. It is often asked how a fly contrives to walk up smooth, perpendicular surfaces, and one answer is that a vacuum is made below a little soft pad which is present on the foot. Another explanation is, that there seems to be a slight exudation of adhesive moisture from the foot. Beetles, which have relatively strong legs, very different from the weak legs of a butterfly, can run with considerable speed, while many insects—one has only to think of a flea or a grasshopper—are pre-eminently leapers. The most primitive insects, the spring-tails and bristle-tails, are entirely wingless, but a spring-tail is an expert jumper. It has at the end of the body an effective leaping apparatus consisting of two elongated prongs, which are bent under the abdomen and pressed down, affording such a leverage when the retaining "catch" is released that the insect springs forward a relatively long distance compared with the size of its body.

From great leaps to the beginnings of flight is an understandable step in progress, and most insects are fliers. There are many patterns of wings, but essentially they are lightly built, mere flattened sacs of skin, often transparent

Photo: J. J. Ward.

PUPA OF DEATH'S-HEAD HAWK-MOTH (MALE).

The larva (a caterpillar in this case) ceases to be active and passes into a state of quiescence, the pupal stage, during which the body is undone and rebuilt. Out of the pupal case the fully-formed insect emerges.

Photo: J. J. Ward.

THE DEATH'S-HEAD HAWK-MOTH.

The black spotted yellow patch upon the thorax gives the impression of a human skull.

and fragile, but beating the air with an extraordinarily rapid motion. It has been calculated that a fly makes 330 wing-strokes in a second, a humble-bee 240, a wasp 110, a dragon-fly 28, and a butterfly 9. The rapidity of the movement produces a hum or buzz. Bees and wasps have two pairs of membranous wings, but the fore-wing and the hind-wing on each side act as a single organ, for the hind-wing has a row of minute hooklets which fit into the curled-over posterior edge of the fore-wing and lock the two wings together. In dragon-flies the two wings are not attached, but the two pairs are co-ordinated by the action of very strong muscles, and the larger dragon-flies are excellent fliers. They are probably helped in steering by the weight of their bodies, the lightness of most insects being against good steering as they are liable to be blown about by the wind.

Whatever the pattern of wing or the speed of the wing-beats, the total distance insects can fly is not great; they seldom wander far afield. Some insects literally fly but once. A may-fly may rise at noon from the water that cradled it, and by sundown its aerial dance of love may be over and its lifeless body be floating on the surface of the pool.

§ 2

Insects are largely creatures of instinct, with inborn capacities for doing apparently clever things, but yet with some degree of intelligence. In an animal's behaviour there is often, no doubt, a mingling of different kinds of activities unified in a way that baffles analysis.

Instincts and Intelligence.

In many cases their behaviour under new conditions, their powers of effectively meeting new ends, go beyond mere instinct. What are we to say of the following?

"The tailor-ants, common in warm countries, make a shelter by drawing leaves together, and their co-operative hauling is admirable; their mandibles are their needles, if you like, but they have nothing to fix the leaves with; what does each do but take a larva in its mouth so that the silk secreted from the offspring serves as adhesive gum.

"The tailor ants nest in trees, and they sometimes find it difficult to bring two rather distant leaves close enough together to be sewn. Then, as Bugnion relates, they have recourse to a perfectly extraordinary co-operation. Five or six will form a living chain to bridge the gap. The waist of A is gripped in the mandibles of B, who is in turn gripped by C, and so on—a notable gymnastic feat. Time does not appear to be of much account, but they work definitely towards a result, and many chains may work together for hours on end trying to draw two leaves close to one another. We could not have a better instance of social co-operation."

An eye-witness, Mr. L. G. Gilpin-Brown, writes from Ceylon:

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"A common harvesting ant of South Europe collects seeds of clover-like plants, lets them begin to sprout so that the tough envelopes are burst, exposes them in the sun so that the germination does not go too far, takes them back underground and chews them into dough, and finally makes this into little biscuits which are dried in the sun and stored for winter use. What a brilliant idea—and yet it cannot be that!—is suggested by the semi-domestication of green-flies by certain species of ants! and what shall we say of the slaves which others

THE LIFE-HISTORY OF A MOSQUITO.

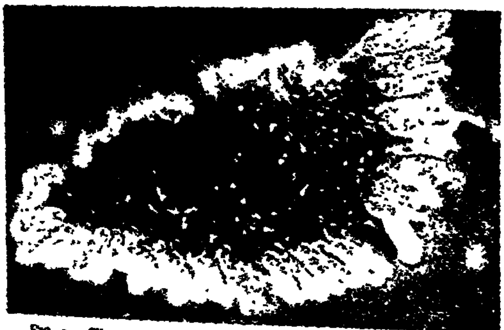

FIG. 1.—The egg-mass of the Mosquito floating on the water. It consists of nearly 300 eggs arranged in the form of a little raft.

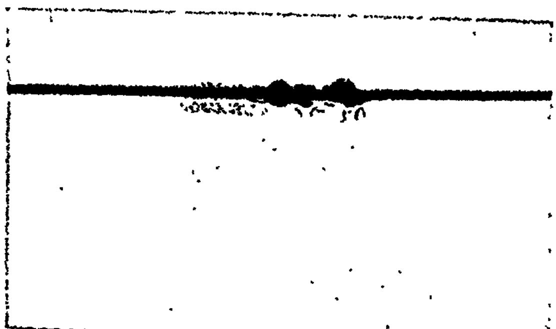

FIG. 2.—Four egg-rafts of the gnat with the young larvæ just emerging into the water.

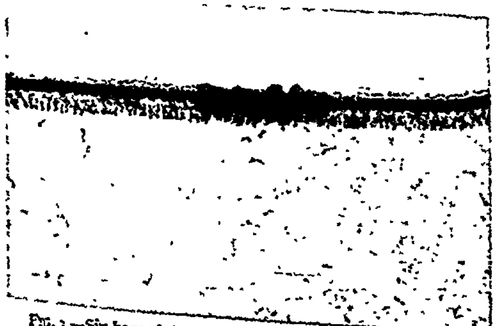

FIG. 3.—Six hours later nearly a thousand larvæ have emerged from the four egg-rafts.

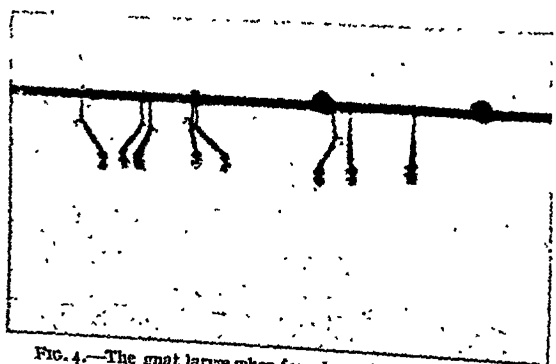

FIG. 4.—The gnat larvæ when four days old. They are resting at the surface and taking in air by their tail-tubes.

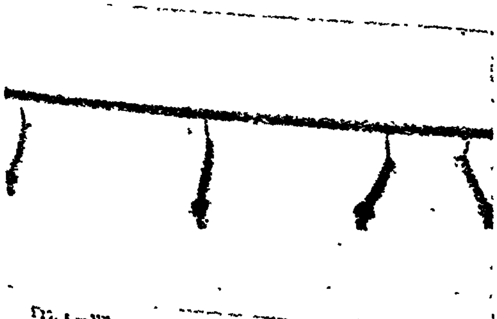

FIG. 5.—When ten days old the larvæ are full-grown. They [illegible] from the under-side of the "surface film" and [illegible] air from above by means of their tail tubes.

[illegible] J. J. Ward.

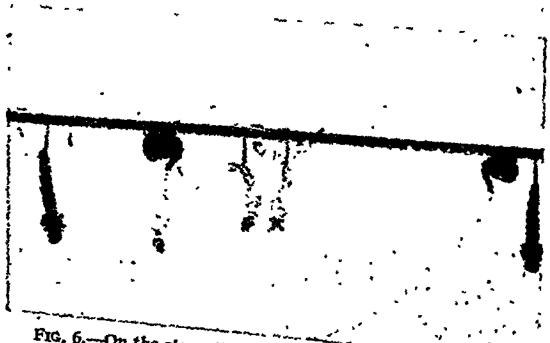

FIG. 6.—On the eleventh day they suddenly moult their skins and change into pupæ, which usually rest passively at the surface, breathing by tubes on the prothorax, but at times show an activity unusual in insect pupæ. One pupa is seen just in the act of casting off the larval skin. (See next page.)

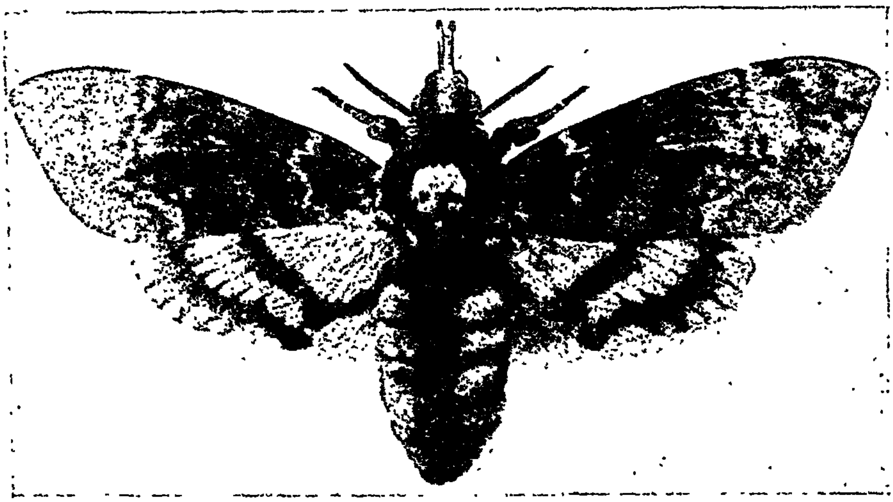

Photo: J. J. Ward.

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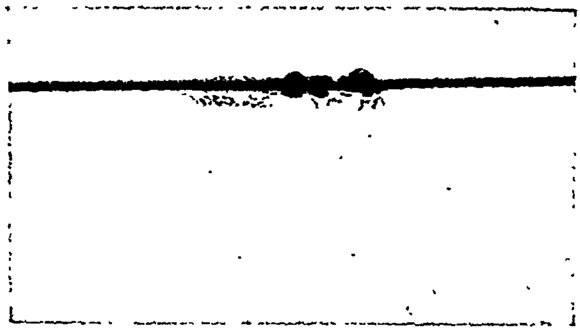

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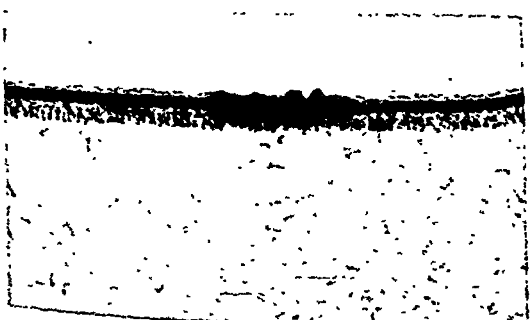

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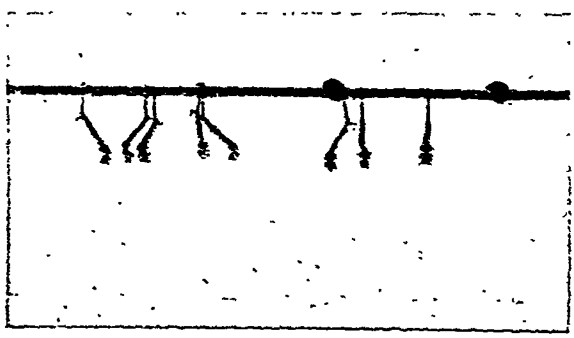
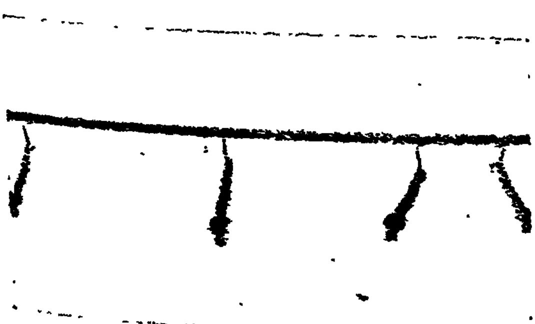


FIG. 4.—The gnat larvæ when four days old. They are resting at the surface and taking in air by their tail-tubes.



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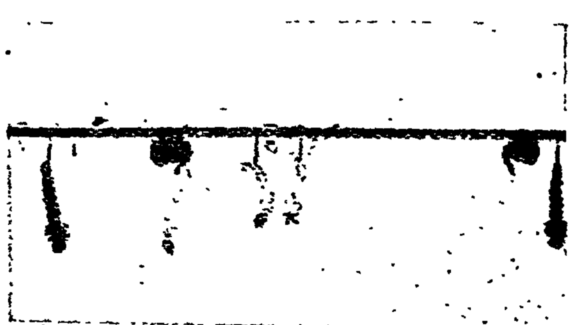

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Photos: *J. J. Ward.*

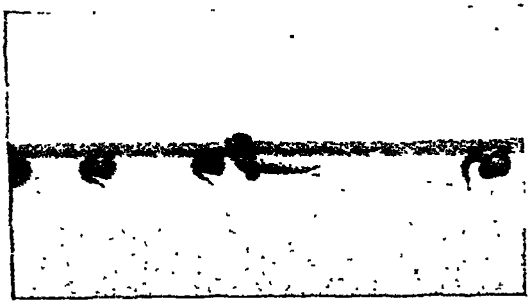

FIG. 7.—On the fourteenth day the pupa bursts its skin at the surface of the water, and the perfect gnat begins to emerge,—

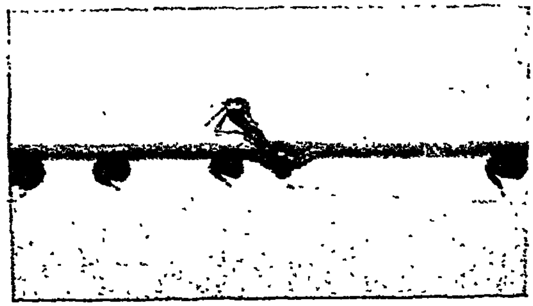

FIG. 8.—and slowly rises into the air, which is henceforth its proper element,—

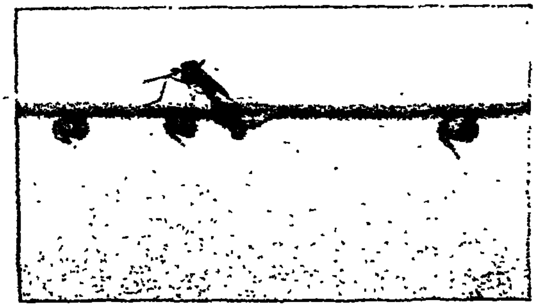

FIG. 9.—finally withdrawing its legs and wings from the last encumbering folds of the pupa skin.

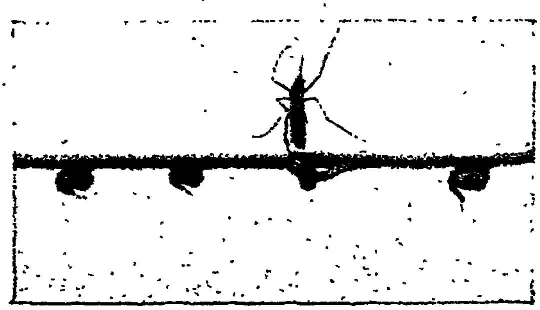

FIG. 10.—Two minutes later it is trimming its wings in readiness for flight.

bluff into service? Many white ants or termites grow highly nutritious moulds in extensive, specially constructed beds of chewed wood, and some of the true ants show a similar habit.

"On wayside plants in early summer we see everywhere the frothy masses called cuckoo-spit, each made by a larval frog-hopper which whips a little sugary sap, a little ferment, and a little wax into a strange persistent foam, protective against enemies and against the heat of the sun, the creature literally saving its life by blowing soap-bubbles. Not far off, on a bare sandy patch, are the deep shafts sunk by the grubs of the beautiful green Tiger Beetle. The grub, with quaint somersault movements inside the shaft, thrusts the loose earth with great force into the walls, and beats them smooth. Eventually it fixes itself near the top of the shaft so that the roof of its head forms a trap-door. When an ant or some other small insect settles down on this living lid, the grub suddenly explodes like a jack-in-the-box, hurling its victim violently against the hard upper edge of the shaft-wall. The sucked body is afterwards jerked out. The world is full of these inventions.

"How are we to understand the behaviour of one of the Digger Wasps which lays its eggs in a sunk shaft, and provisions this with paralysed caterpillars? While the hunting and storing are in progress, the wasp shuts the mouth of the shaft after each visit, but does so in a rough-and-ready fashion. When the larder is full, however, it seals the entrance with earth and makes a neat job of it; nay, it takes a minute pebble in its jaws and beats the earth smooth. Who said animals could not use tools? It seems that using the pebble is not part of the instinctive routine, but is an individual touch, probably with more vivid awareness than is associated with the rest of the agency. But the difficulty is to think of the origin of either the routine or the finishing touch without postulating intelligence, or, at least, some appreciation of significance."[1]

Homing.

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[1] J. Arthur Thomson, *Secrets of Animal Life.*

An interesting experiment suggested that bees build up a knowledge of the country round about the hive. Professor Yung of Geneva took twenty bees from a hive near the lake and liberated them at a distance of six kilometres in the country. Seventeen returned to the hive, some within an hour. Next day the successful seventeen were taken on a boat to a distance of three kilometres on the lake. When liberated they flew off in all directions, but apparently they missed the necessary signposts, for none of them found their way home. On the other hand, experiments have given results that indicate that bees have a "sense of direction," comparable to that of carrier-pigeons. Even bees with their eyes obscured have been known to make a "bee-line" for the hive from considerable distances. But there is no doubt that bees make cautious and systematic trial "flights of orientation" when a hive is placed in a new position.

An outstanding feature of Ants is that of instinctive socialisation. They do not live unto themselves, but for the general good of the community. They are indefatigable, but whether they toil consciously for the sake of anything, or what we are to read into their capacity for unified action, who shall say? "It is difficult to accept the opinion of some naturalists that instinctive behaviour is unaccompanied by any awareness of meaning or feeling of the end. Whenever this difficulty is obvious, it is customary to say that intelligence has for the time being taken the reins. In any case, the *facts* are wonderful enough."

Intelligent Behaviour.

It is among the Social Insects that the most pronounced evidences of intelligence are found. "Intelligence is an eminently social faculty," as Kropotkin says. "Language, imitation, and accumulated experience are so many elements of growing intelligence of which the unsociable animal is deprived. Therefore we find, at the top of each class of animals, the ants, the parrots, and the monkeys, all combining the greatest sociability with the highest development of intelligence. The fittest are thus the most sociable animals, and sociability appears as the chief factor of evolution, both directly, by securing the well-being of the species while diminishing the waste of energy, and indirectly, by favouring the growth of intelligence."

Mutual help is practised extensively among insects of various kinds. The Burying Beetles, which usually lead a solitary life, call to their aid a number of their fellows when there is a corpse to be buried. Many caterpillars weave a silken web to make a shelter for a whole brood, while the full-grown Procession Caterpillars march together from their feeding-ground on the trees to a soft place on the ground where they can bury themselves and become moths. Locusts display gregarious habits also which are of mutual advantage; for instance, it is a common practice for the wingless young to make a living bridge over a moderately broad stream, plunging into the water and grappling for sticks and straws, and scrambling for a breathing space on their comrades' bodies, till the whole swarm passes across the stream. Comparatively few are drowned, as the same individuals are seldom in the water the whole time. Such associations for mutual aid suggest the beginnings of societies, but they are not nearly so highly evolved as those seen among the termites, ants, bees, and wasps, where the social habits extend to the welfare of the young, and co-operation reaches a high level. Kropotkin says, "If we knew no other facts from animal life than what we know about the ants and the termites, we already might safely conclude that mutual aid (which leads to mutual confidence, the first condition of courage) and individual initiative (the first condition for intellectual progress) are two factors infinitely more important than mutual struggle in the evolution of the animal kingdom." The fact is that in the struggle for existence, which includes all the answers back that living creatures make to environing difficulties and limitations, sociality pays just as well as intensified competition, or, it may be, *pays better*.

§ 3

THE STORY OF ANTS

Of all insects, Ants must be placed on the highest level, for none have better mastered the art of living together in a mutually beneficial manner, and many ant communities show considerable elaboration. Let us, then,

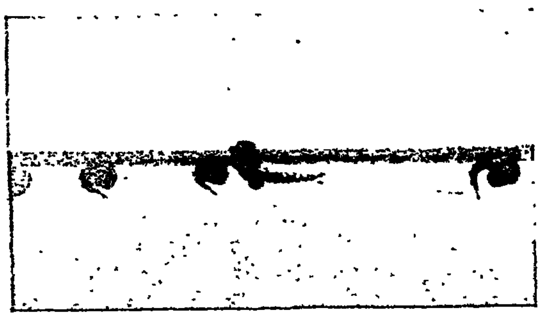

FIG. 7.—On the fourteenth day the pupa bursts its skin at the surface of the water, and the perfect gnat begins to emerge,—

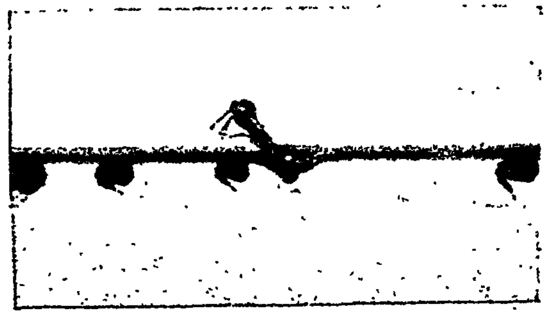

FIG. 8.—and slowly rises into the air, which is henceforth its proper element,—

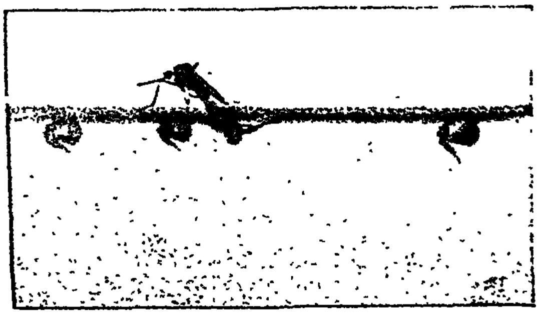

FIG. 9.—finally withdrawing its legs and wings from the last encumbering folds of the pupa skin.

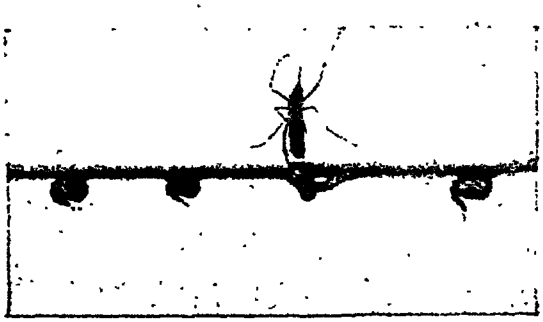

FIG. 10.—Two minutes later it is trimming its wings in readiness for flight.

bluff into service? Many white ants or termites grow highly nutritious moulds in extensive, specially constructed beds of chewed wood, and some of the true ants show a similar habit.

"On wayside plants in early summer we see everywhere the frothy masses called cuckoo-spit, each made by a larval frog-hopper which whips a little sugary sap, a little ferment, and a little wax into a strange persistent foam, protective against enemies and against the heat of the sun, the creature literally saving its life by blowing soap-bubbles. Not far off, on a bare sandy patch, are the deep shafts sunk by the grubs of the beautiful green Tiger Beetle. The grub, with quaint somersault movements inside the shaft, thrusts the loose earth with great force into the walls, and beats them smooth. Eventually it fixes itself near the top of the shaft so that the roof of its head forms a trap-door. When an ant or some other small insect settles down on this living lid, the grub suddenly explodes like a jack-in-the-box, hurling its victim violently against the hard upper edge of the shaft-wall. The sucked body is afterwards jerked out. The world is full of these inventions.

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[1] J. Arthur Thomson, *Secrets of Animal Life*.

take the case of ants as a particular illustration of the distinctive features of insect societies.

The Marvels of the Ant-hill.

Here we have "a community of separate individuals with more or less of a corporate life, and with the power of acting as a unity." Many Ants live for a number of years, so that one generation may teach another the profitable arts which lead to the success of the community. The welfare of the species is the important matter, and the individual is often sacrificed, as well as specialised, for the common good. There are three types of individuals—winged males, winged females, and wingless "workers" or undeveloped females; and the workers may be of different kinds, large and small—or with huge mandibles in the "soldier" type. We see a division of labour. The busy workers tread the neighbourhood of the nest into a pattern of "ant roads" by which they come and go on their foraging expeditions. Smell counts for much in way-finding. Within the nest, the workers have their home duties, they look after the young, feeding them and carrying them from room to room to secure a suitable temperature, and they bite open the cocoons when the perfect insects are ready to emerge.

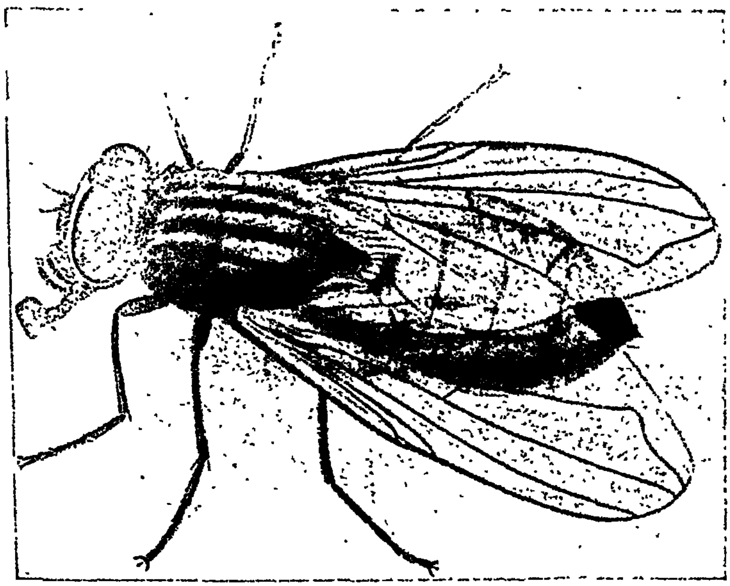


Photo: James's Press Agency.

HOUSE-FLY (*MUSCA DOMESTICA*).

It is bred in rubbish heaps during the summer months. The House-Fly is an agent in carrying typhoid germs, which readily adhere to the numerous hairs seen on the fly's body and appendages. (The Blow-fly, or Blue-bottle, lays its eggs on dead animals, and on joints in the larder if it has access to them.)

Mutual aid and harmony seem to reign within the community, but there are terrible wars with other species, which are carried out in a well-organised fashion. Ants have the instinct of acting together and seldom make individual attacks, but they never seem to hesitate to sacrifice themselves for the protection of the community. Sometimes these warlike expeditions are initiated with a definite end in view, that of capturing slaves. For instance, the Amazon Ants, which have jaws well suited for warfare but inconvenient for the peaceful occupations of life, habitually keep slaves to wait upon them. Professor Wheeler thus describes them: "While in the home nest they sit about in stolid idleness or pass the long hours begging the slaves for food, or cleaning themselves and burnishing their ruddy armour, but when outside the nest they display a dazzling courage and capacity for concerted action." Scouts report their discovery of a Brown Ant colony, and a raid promptly follows, the Amazons returning victorious with a large number of prisoners, which become faithful slaves. Darwin's suggestion "of the origin of slave-making was that many ants capture the pupæ of other ants for food, that some of the stored pupæ might be unintentionally reared, that if their presence in the community was not resented but proved useful, the slave-making habit might make ground."

Like the Termites, the true Ants frequently have guests within their homes. Certain little crickets find shelter and abundant food in this hospitable haunt. They beg food from the ants, and usually they shamelessly steal from the newly-fed young ants. Beetles, too, with a peculiar fragrance that makes them welcome guests, persuade the ants to share the sweet substances they carry in their crops, by stroking them till they deliver up the coveted dainty. One species of ant carries mites about on the body, feeding them and caring for them, but

apparently deriving no benefit from them. Evidently ants are fond of keeping pets!

One of the peaceful occupations ants pursue is keeping "cattle." Their "cows" are little aphides or green flies, which they cherish for the sake of the sweet "honey-dew" that exudes from their bodies. Possibly at first it was simply a matter of feeding at the same table, when the ants would dip over the sugary fluid and get into the way of licking the green flies. The eggs of a certain aphis, which are of no direct use to the ants, are brought into the nests and protected carefully from the severities of winter until the warm weather comes, when the young aphides are brought out and put on their food-plant, walled in by little "cattle-pens" of earth. By keeping these eggs safe for six months the ants ensure a supply of the food delicacy during the following summer—a truly remarkable case of prudence!

In North America there are "agricultural ants" which weed a space near the nest and only allow plants with edible seeds to grow there. These seeds they gather in due season, and store in the form of little biscuits which are made from a chewed-seed dough dried in the sun. *Another industry is the cultivation of fungi for food*—another point in which they agree with the Termites—and this habit is seen among the Leaf-cutting Ants. The fungus is grown in the underground nest on a spongy framework of chewed leaves, and the ants not only keep undesirable fungi from growing amongst their peculiar delicacy, but they keep their speciality from fructifying, which would spoil it for their purpose.

The Wonderful Leaf-cutting Ant.

Much has been added to our knowledge of the Leaf-cutting Ants by Mr. Beebe, who, in his fascinating book *The Edge of the Jungle* (1921), gives us an account of his own observations of a species of Atta in British Guiana. He had the good fortune to see, at one time, a royal procession leaving the nest in preparation for the nuptial flight. The great queen laboured painfully up the tunnel far away from the real entrance to the nest. Behind her came the kings, much smaller than she, but large in

DRIVER-ANTS ATTACKING A SNAKE.

The Horned Viper, shown in the illustration, was attacked whilst casting its skin. The ants covered every portion of its body, hanging on by their pincer-like jaws. The snake writhed and struggled for a quarter of an hour, but in the end was killed and eaten by the ants.

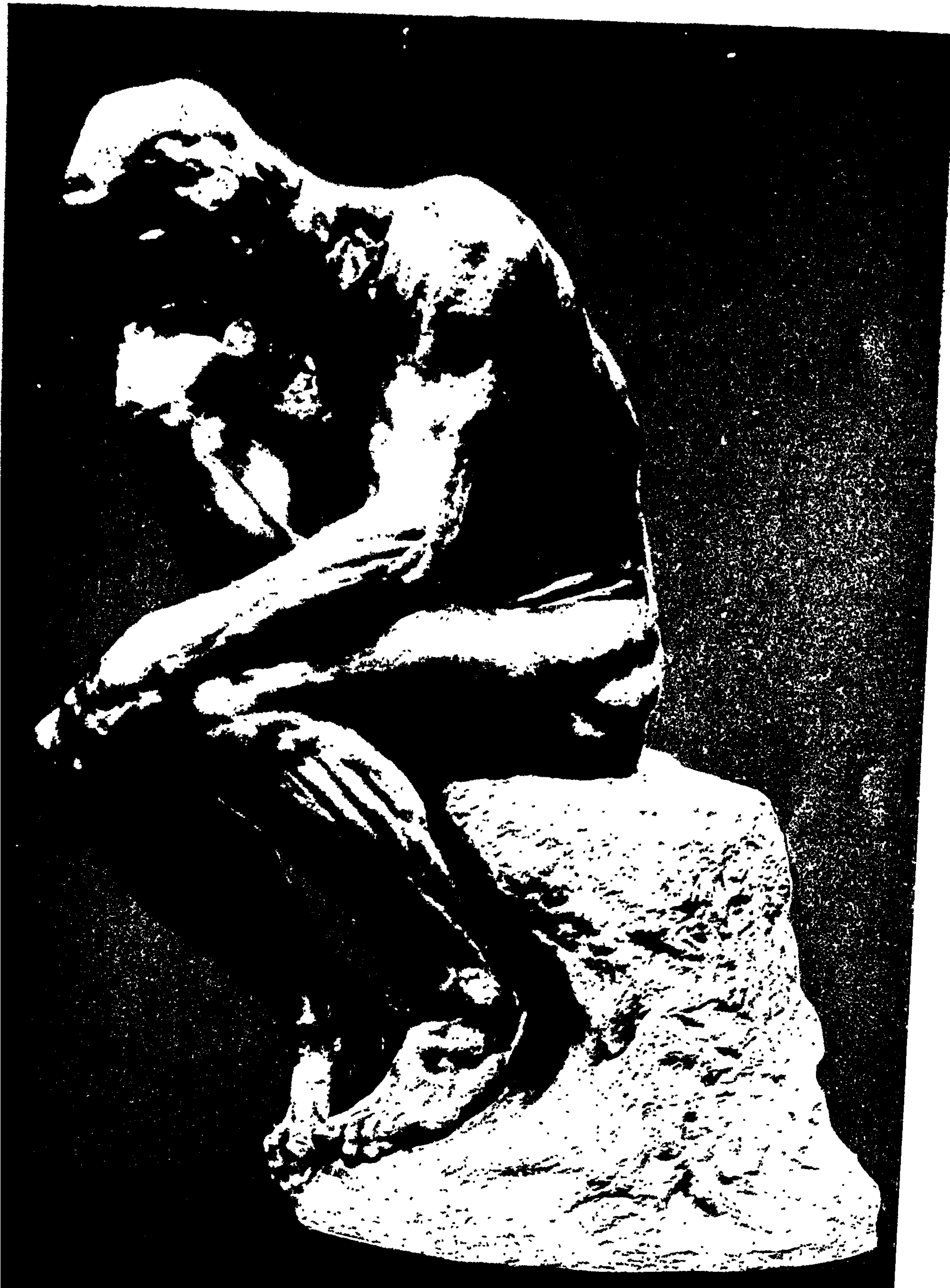


Photo: Bulloz

THE THINKER
From a Statue by Rodin

through a very thorough scraping and cleaning, and they not only submitted with a good grace, but turned over on their backs to facilitate the process.

Spraying with formol disorganised the colony, which broke up in long festoons, and moved away, carrying eggs and larvæ. Next morning it was found that about a third of the ants had remained on the floor in charge of larvæ at the critical stage of passing into the pupal stage. The workers were very busy gnawing wood to dust, and rags to shreds, to provide the light covering which seemed necessary before the larvæ would begin to spin. The following morning the whole hoard had disappeared.

Termites or "White Ants" are not related to the true Ants, but their achievements are equally wonderful. They are abundant in many warm countries, notably tropical Africa. They live together in great communities, sharing a many-chambered earthen nest. The hills or termitaries which they build are often twice a man's height and strong enough to stand upon. In South Africa telegraph posts have to be made of iron to resist their jaws. There is striking division of labour, as with the Black Termite so abundant in Ceylon. When on the march the Black Termites move in great armies, sometimes comprising 300,000 individuals. It has been computed that there are 200 "soldiers" to every 1,000 workers, the number of soldiers guarding a march varying with the danger. The long troop of workers marches between two lines of soldiers. Their tactics are nothing short of extraordinary: there are guides and scouts searching out new lines for foraging. "Very carefully, step by step just like cats, they slink forward, one behind the other, and if the foremost detects anything the least suspicious, he draws nervously back, pulling his 'brave' comrades after him." There are "soldiers" that restore order in the ranks where there is panic; the orders seem to be given through the antennæ or by a quivering of the whole body. Professor Bugnion tells of a war which lasted for three days. The Black Termites often wage a bitter battle with the well-known Tailor-ant, *Œcophylla*; when the latter draw near the termites squirt full in their faces drops of a secretion or fluid which seems to drive the true Ants almost crazy.

§ 4

THE STORY OF BEES

In the Hive Bees (Apis) we have a further illustration of insect communal life. Whatever the nature of the communal life of bees may be, we cannot liken it to that of human society. The one is run on predominantly instinctive lines, the other is predominantly intelligent.

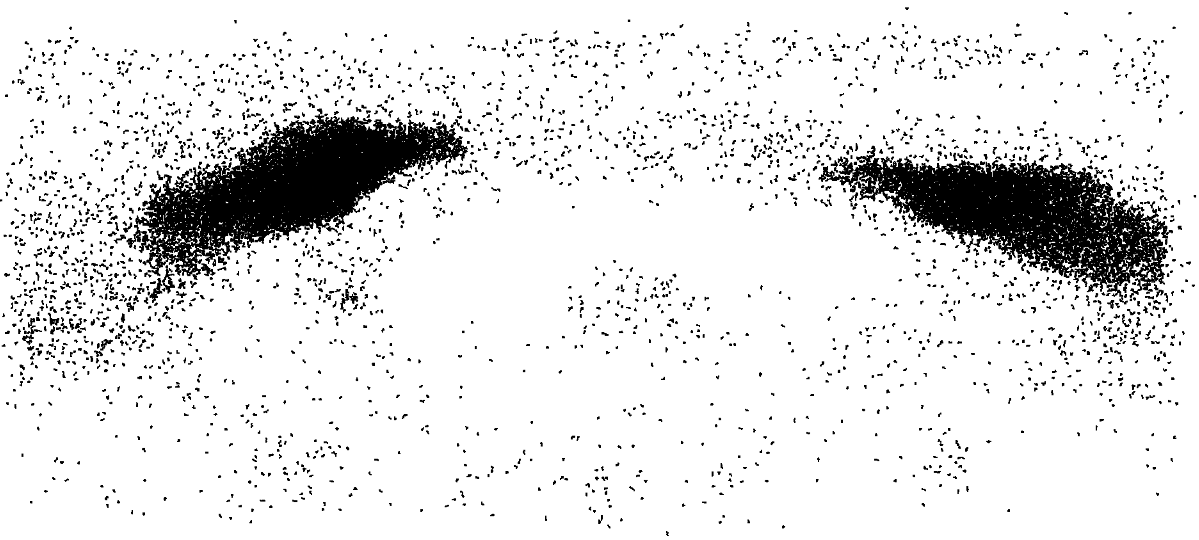
The Beehive.

An element of *permanence* distinguishes their communities, for many workers as well as the queen survive the winter. To the industry and food-storing habit of the Hive Bee is probably due their complex social life; the storing has enabled the community to survive unfavourable seasons and become permanent. When spring reawakens the earth and the willow-trees are bedecked with catkins, and gorse and violets and primroses send out a fragrant invitation, the bee world resumes its busy life again. The workers set to work to "spring-clean" the hive and build new combs of hexagonal cells to accommodate the eggs the queen has again begun to lay. Some of the workers sally forth to bring in fresh stores of pollen and honey, while others are nurse workers in charge of the fast-filling nurseries. In early summer the hive is a prosperous and busy city, inhabited by three distinct types of individuals. The head of the community is the queen, not by reason of her wits, for her daughters far surpass her in brains and activity, but because she is the mother bee, who alone can increase or restore the population.

The Queen.

One of the most remarkable facts about hive bees is the apparently psychical dependence of the community on the presence of the queen. If she is removed, the bad news spreads quickly through the hive and there is a strange disorganisation. When the bee-keeper replaces her, the good news soon circulates, and there is harmony once more. According to some authorities, the queen has a peculiar odour which is reassuring to the workers. There is no doubt that smell counts for much among bees.

The queen bee is concerned only with egg-laying; the life of the hive is sustained by the worker bees, which are active, intelligent, but sterile females, with their reproductive systems in a state of arrested development. Thirdly,



diet of pollen and honey. Then the larvæ spin cocoons and the workers shut the cells with little caps of porous wax, and leave their charges to a thirteen-day pupation, after which yet another generation of worker bees bite off the roofs of their cradles and join in the busy life of the hive. In larger cells the queen deposits eggs which are not fertilised, and these develop into drones. Still later in the season "royal" cells are constructed, in which the queen lays fertilised eggs, identical with those laid in the ordinary worker cells, but the grubs which hatch out receive a special "royal jelly" from the mouths of their attendants, instead of the usual fare of masticated pollen, and the effect of this diet is to make the grubs develop into "princesses" instead of workers.

It should be noted that a queen bee receives from a drone in the course of her "nuptial flight" a store of sperm-cells with which she may fertilise the eggs she lays during the next year or more. It depends on the egg-laying movements of the queen whether the laid egg is fertilised or not.

The Swarm.

Then comes the remarkable upheaval of the busy hive—the departure of a "swarm," headed by the queen bee. Whether swarming is due to the overcrowded state of the hive, or to the queen's excitement when her young rivals are stirring in the royal cradles, or to a sudden desire on the part of the workers, a harking back to the time when there were no hives and motherhood was not given only to one among thousands, a desire to break out of their "prison bounds of order, commendable toil, chill, maidenly propriety," who shall say? But suddenly the routine of the hive is broken through, work is suspended and many of the workers become restless and excited, and gorge themselves with honey till at a given signal the swarm issues from the hive, "in a tense, direct, vibrating, uninterrupted stream that at once dissolves and melts into space, where the myriad transparent furious wings weave a tissue throbbing with sound."

The mad, joyous dance in the sunlight over, the swarm returns to earth, and now there is the morrow to consider and a new home has to be built. Scouts go out, and when they have found a suitable site the workers at once begin to fashion a new comb, in which the queen lays eggs, and so a new city springs up. The hexagonal cells of the combs are made of thin plates of pliable wax, which comes from little pockets on the bee's abdomen. To start the secretion of the wax great heat is needed, so the bees gather together in a great pendant mass till "a strange sweat, white as snow and airier than the down of a wing, is beginning to break over the swarm." The worker bee removes the wax scales from her body with a pair of pincers she has at one of her knee joints, and then chews

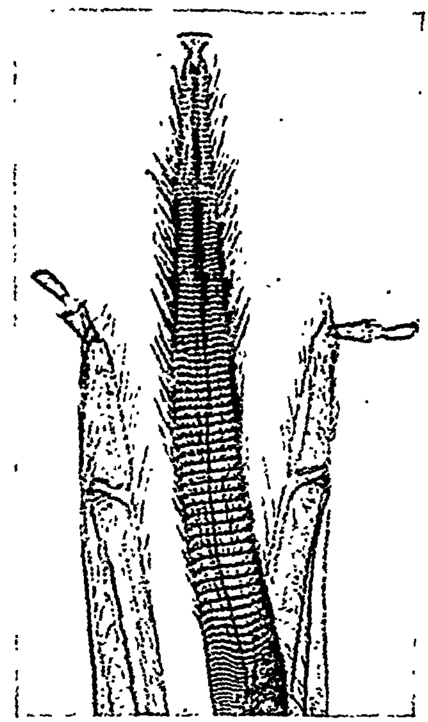


Photo reproduced by courtesy of F. Davidson & Co.

TONGUE OF HIVE BEE.

By means of this long tongue the worker-bee is able to extract from flowers the nectar which is afterwards stored as honey in the hive.

them into a soft paste which can be moulded into the delicate fabric of the cells.

Honeycomb.

The bees' comb is one of the wonders of the world. In spite of its extraordinary fragility it is able to suspend a weight thirty times as great as its own. A small block of wax attached to the roof of the hive makes the foundation, from which the layers of cells grow out downwards and sideways, leaving a gangway for the streams of bees to pass to and fro. The usual shape of the cells is hexagonal, individually well suited for the cylindrical body of a grub, together ideally

constructed to prevent waste of space. But bees adapt themselves to unusual circumstances and build triangular, square, or other cells in odd corners if the need arises. The cells are not quite horizontally placed, having a slight upward tilt which prevents the spilling of thin honey. Extreme delicacy of touch is required in the moulding of the plastic wax, for the $\frac{1}{180}$ part of an inch is the thickness of the tissue-paper-like cell-walls.

While the new colony is rapidly growing up, life continues in the old hive: it is, in fact, about to renew its youth. One of the princesses is awakening, and the remaining workers are watching over her. She appears from the shelter of the royal nursery, and the workers brush her and clean her and caress her. Impelled by some strange instinct, she immediately seeks the other cradles, tears open the cells and relentlessly stings her sisters, her possible rivals, to death! A few days later, on a bright and sunny day, she leaves the hive for her nuptial flight. She soars aloft into the blue sky followed by a crowd of drones from neighbouring hives, and somewhere in the solitude of the blue the strongest male overtakes her and meets love and death in the same instant; and the bride-widow returns to the hive.

The Nuptial Flight.

For the remainder of the summer the busy life of the hive goes on as before, the queen perpetually egg-laying, the workers foraging and nursing, the drones leading a life of ease. But one day the decree goes forth that those that do not work shall not eat, indeed shall not live; and the massacre of the males begins. Vigorously and pitilessly the long-suffering workers at last turn on the drones and slay them all.

Massacre of the Males.

Flowers are becoming scarce, and the days are short and chilly, so the bees cease their labours and prepare for the long sleep of winter, if sleep it can be called, for the life of the hive is slackened, not completely arrested. The bees gather together in a great cluster, with their queen in their midst, and by the beating of their wings they keep up a current of warm air. The bees nearest the store cupboards pass the honey to their neighbours, and so food is circulated through the drowsy mass, enough to keep the fire of life glowing, ready to burst into flame again with the return of spring.

Among different kinds of bees there are different degrees of sociability. Some, such as the Leaf-cutting Bee, are quite solitary; others show a certain amount of co-operation combined with a large amount of independence.

The Humble-Bees (Bombus) live in communities which last for one season only. The queen humble-bee, after her autumn nuptial flight, creeps into a hole under a sun-warmed bank and there lies torpid throughout the cold weather. Spring awakens her and she sets to work to prepare for her expected brood. She secretes wax, makes a few cells, and lays her eggs in these. She has herself to discharge the whole labour of foraging for honey and pollen, keeping the cells clean, kneading the bee-bread, and feeding and tending the hungry larvæ. She is a queen in the sense of being the mother of the whole colony, but she is a very hard-working queen for a time. Later, when the first batch of young ones, which are always workers, are fully developed, they take the domestic details on themselves, and the queen can now devote herself to her true business of motherhood. As in the case of wasps, the community dissolves at the end of the summer, workers and drones all dying, but a few young queens surviving through the winter to found the colonies of the following year. In this and in many similar cases it is difficult to know whether one should speak of a large family or of an incipient society.

The Humble-Bee.

§ 5

Even Solitary Wasps instinctively provide for their young, though they die before these hatch out. They deposit the eggs in a shelter and leave with them a larder of fresh meat, in the shape of living insects rendered unresisting by the paralysing effect of the wasp's sting on their nerve-centres. The Social Wasps live in communities which last from spring to autumn. Winter is the time of inactivity, but in some secluded spot, a cranny in a wall or a sheltered nook in a rubbish heap, the queen wasp, who mated at the end of last season, is sleeping her winter sleep, tiding over the hard months in a state of passiveness in much the same attitude that her body assumed during the pupa stage. With the coming of spring she reawakens, and the season's activities

The Story of Wasps' Nests.

are soon in full swing. The queen's first care is to choose a suitable site for the nest she is about to build, and a cavity in the shelter of the gnarled roots of an overthrown tree is as good as any. Then she sets to work to collect wood-fibre, which she rasps with her jaws from posts and palings. This wood-pulp she kneads with her saliva into the "paper" with which the nest is built. She spreads the first layer on the root she has chosen as the foundation from which to hang the structure, and gradually, hour by hour, pellet by pellet, she moulds a disc, and then a stalk, and then a canopy to shelter the first layer of cells. In each cell as it is completed she deposits an egg, which she cements to the cell-wall, for the open end of the cell is directed downwards.

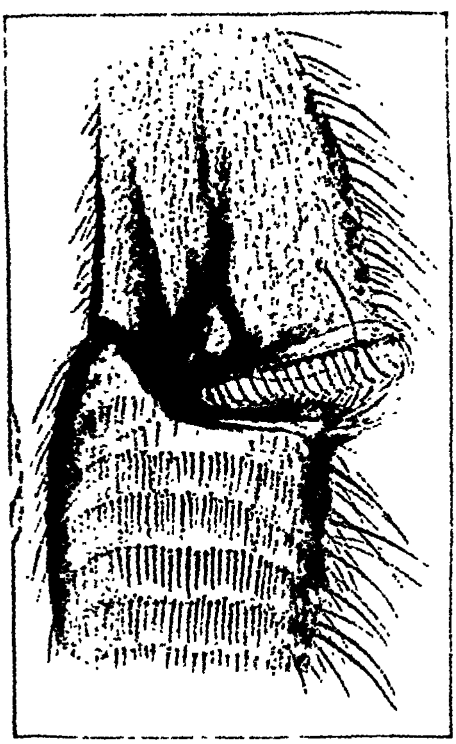


Photo: James's Press Agency.
POLLEN BASKET ON HIND-LEG OF HONEY-BEE (WORKER).
Pollen, kneaded into a little ball, is carried from the flower to the hive in receptacle shown.

In a few days the legless grubs emerge, and the queen becomes a nurse as well as a home-builder, until the older grubs mature, and a staff of worker wasps is ready to take on the manual labour and allow the queen to devote herself to egg-laying. The workers add to the original comb and suspend a new storey from it by little stalks. One storey is added after another. The rounded outer covering is also extended, by being hollowed out inside and added to outside. This outer envelope may consist of as many as a dozen layers of the paper, which is a water-proof and non-conducting material, so that the necessary temperature for the development of the young is kept up. The entrance opening of the envelope is always at the foot of the pendant nest, and all the openings of the combs point towards it, so that the young are reared in inverted cradles.

The young wasp grub at first keeps its position by clinging with its tail to the egg envelope while it pokes its head out for food, but later it uses its jaws and a sort of sucker-foot on its tail as grasping organs. If it does happen to fall out, the worker nurses will probably throw it out of the nest, just as they do with rubbish when they are cleaning. The first thing the fully formed young wasp does, if it has safely passed through its head-downwards larval and pupal stages, is to crawl about and visit the grubs, tapping them on the head till they emit a tiny drop of fluid, which the young wasp licks greedily. Then it is ready to help its mother with the housework, and in a few days is strong enough to go out on foraging expeditions. The mother wasp also visits the grubs for this delectable drop.

How the Wasp Works and Dies.

The young wasp's duties at first consist mainly of paper-making and building, for the nest is continually growing. She works backwards so that she does not tread on the newly applied pulp, and she moulds her material to the proper thickness, testing it with her feelers. But after a week or two her salivary glands are exhausted, so that she has to give up the manufacture of paper and turn to the older wasp's task of caring for the young, feeding them with the soft parts of insects and occasional sips of fruit-juice or nectar, and cleaning them with care. So through the summer the busy life of the community goes on. The queen has laid thousands of eggs, and a great army of her daughters is engaged in enlarging the nest—which may now have seven or eight tiers of combs enclosed in a great ball of grey paper—in keeping it scrupulously clean, and in caring for the rising generations. Some of these workers, though they are never impreg-

nated, may occasionally lay eggs, which, like the unfertilised eggs of the queen, invariably develop into males.

As summer wanes, the workers build larger cells in the lower combs. These are the royal nurseries in which a brood of perfect females, not sterile workers, and males are reared. On this brood the future of the race depends. A few weeks, and a great change takes place—summer is still here and the wasp-colony is at the height of its prosperity, a healthy, active community; then the chill finger of autumn passes over it, and the first shiver marks the beginning of the decline of the colony. Prosperity is succeeded by starvation. There are no stores to fall back on, and deadly numbness and demoralisation break down the orderly routine of the nest. The exhausted workers die in their thousands, and with them the parent queen. None but the young royalties survive, and the males only long enough to mate with the young queens: thereafter they also die. The young queens destined to found new colonies next spring alone escape the common fate, but the demoralisation shows itself in them too, for they devour the remaining eggs and larvæ, and on this rather cannibal fare they are able to survive the winter.

§ 6

LIFE HISTORIES

The food of Insects is extremely varied, not only in different species, but also within a single life-history, and it naturally follows that there is much variety in the ways of obtaining it, and, in particular, in the structure of the appendages associated with the mouth. Insects depend greatly on their sense of smell when in search of suitable food, and the organs of smell, minute olfactory pits or bristles, are found chiefly on the antennæ. Some insects move their feelers markedly on coming near strong-smelling substances, and some are unable to find their appropriate food without the aid of their antennæ. For instance, Carrion Beetles which had had their antennæ removed were found to be incapable of locating their evil-smelling food. A very striking example of change of diet is seen in the life-history of a butterfly, such as the common Cabbage White Butterfly. The small, sculptured eggs are laid in large numbers on the plant which is to form the food of the caterpillars. The caterpillar emerges from the egg as a worm-like, short-legged little animal, green against the green of its natural haunt, with simple eyes, short feelers, stumpy abdominal "pro-legs" in addition to the three pairs of jointed thoracic appendages, and strong, hard jaws well suited for gnawing green food. Its business in life is to feed and to grow, and it feeds rapidly and almost continuously. It may eat many times its own weight in a day, but probably only digests the fluid part of the food. It outgrows its inexpansible chitinous covering, and has to moult it, an exhausting and dangerous process. Then it feeds and grows and moults again, until at its limit of growth it passes into a resting phase. It becomes a pupa, or chrysalis.

Story of Cabbage White Butterfly.

The Cabbage White Butterfly larva suspends itself in a quiet corner by a silken thread, with its tail against a support, and the larval skin forms the pupa case, but many other pupæ (e.g. many moths) have the additional protection of a cocoon, either of pure silk secreted at the jaws, or of silk mixed with leaves, moss, or other extrinsic matter. The larva (i.e. the caterpillar) now undergoes the great change which is called metamorphosis. Within the cocoon the body of the larva is broken down and is built up again on a new architectural plan. When the reconstruction is completed the fully-formed insect emerges. What a contrast! It is now an intensely active butterfly, having left behind it the shrivelled skin of the creeping caterpillar, and for a brief season it lives its aerial life, growing not at all, feeding but little, and then only on liquid nectar by means of the long sucking-tube so different from the strong biting jaws of the caterpillar: hunger is no longer the preoccupation; the butterfly lives for love, and before it dies it deposits its eggs on the green plant which it cannot itself eat, but which forms the right food material for the offspring it does not survive to see.

Beetles.

Beetles are essentially biters, with very strong and hard mouth-parts, one pair of which, the mandibles, are sometimes of relatively enormous size, with sharp saw-like edges. Many of them, such as the Weevils, are vegetarians, feeding on green plants or on the

Photo: J. J. Ward.

TREE WASP.

A queen wasp biting off bits of wood which she chews into a pulp, the raw material which she manufactures into the familiar grey "paper" that forms the walls of her home.

bark and wood of trees, but many others are carnivorous and destroy numbers of wireworms, "leather-jackets" (the larvæ of the "Daddy-long-legs"), Saw-Fly larvæ, and other insects which are detrimental to crops. Others, again, feed on the decaying flesh of dead animals, and the busy "Burying Beetles," which join forces in their work, act as useful bands of scavengers.

An important Linkage.

Other groups of Insects, with quite different mouth appendages, belong to the sucking types, which feed on liquid food. Instead of cutting, toothed jaws, they have sucking-tubes, often accompanied by sharp piercing needles as in the Mosquito, which pierce the skin and suck in the blood of the victim. The nectar of flowers is another great source of liquid food, and is sought by Bees, Butterflies, Moths, and others which have sucking mouth-organs. Perhaps the most important linkage in the whole system of animate nature is the linkage between flowers and their welcome insect visitors. For these visitors secure cross fertilisation, and this is often essential to seed-bearing.

§ 7

Life-histories.

There are various ways in which the young forms of Insects hatch out from the shells within which they develop. Some caterpillars eat through the shell; some maggots wriggle until it breaks; and some larvæ have special instruments for the purpose. Thus the larval flea has a temporary piercing organ on its head. Many larvæ differ markedly from the adult forms, and they are of several different types; they may be active, long-legged, flat-bodied (campodeiform) larvæ (very like the primitive Bristle-tails), e.g. many beetle larvæ, May-Flies, Stone-Flies, etc.; or they may belong to the more worm-like (eruciform) group, such as caterpillars (i.e. young of moths and butterflies), maggots, and various grubs, and these may be more sedentary in habit. In the course of the life-history of many insects a marked change of form takes place—metamorphosis. According to the degree of metamorphosis, insects are divided into three groups. (1) When *no* metamorphosis occurs and the young are hatched as miniatures of the adults, e.g. the most lowly insects, the Springtails and Bristle-tails. (2) An intermediate group comprises those insects which show partial

Photo: J. J. Ward.

NEST OF WASP MADE ENTIRELY BY THE QUEEN.

The nest was built in between the stones of a wall, and one stone has been removed to expose it. This was the nursery for the first generation of worker wasps, which, when mature, would enlarge the home for the rapidly increasing family.

metamorphosis. In this type the insect is able to move and feed practically throughout its development; the change is a *gradual* one. Through a series of moults, made necessary by the inexpansible armour of chitin, the insect reaches the adult condition.

For instance, the young Locust, as it emerges from the egg, has a pale, soft body swathed in transparent skin. It sheds its mantle, and, gaining strength in the sunlight, becomes firm and black, only differing from its parents in size, colour-markings, and the absence of wings. It feeds hungrily on vegetable substances, and grows and moults, each moult leaving it larger, brighter, and hungrier than before, until after the third moult its wings begin to show. The moulting process lasts only about half-an-hour, and the locust only stops feeding for a few hours. No phase of torpor or quiescence occurs in this "half-metamorphosis" type, and after the fifth skin-casting the locust is a perfect, winged insect, soft and helpless and very vulnerable for a time, but rapidly regaining firmness and vigour.

(3) When complete metamorphosis occurs, a quiescent pupal or chrysalis stage comes between the larval and adult stages. Growth occurs during the larval stage, a period of voracious feeding, rapid growth, and numerous moults. The larva eats far more than is necessary to maintain its life, and lays up a reserve store which provides for the resting pupal stage which follows. The pupal stage is a time of little or no external activity but great internal changes. The larval tissues are broken down and their substance is reconstructed into the very different tissues of the adult. From the pupa case the adult insect emerges, different in form and habit, winged and aerial. Metamorphosis implies far more than

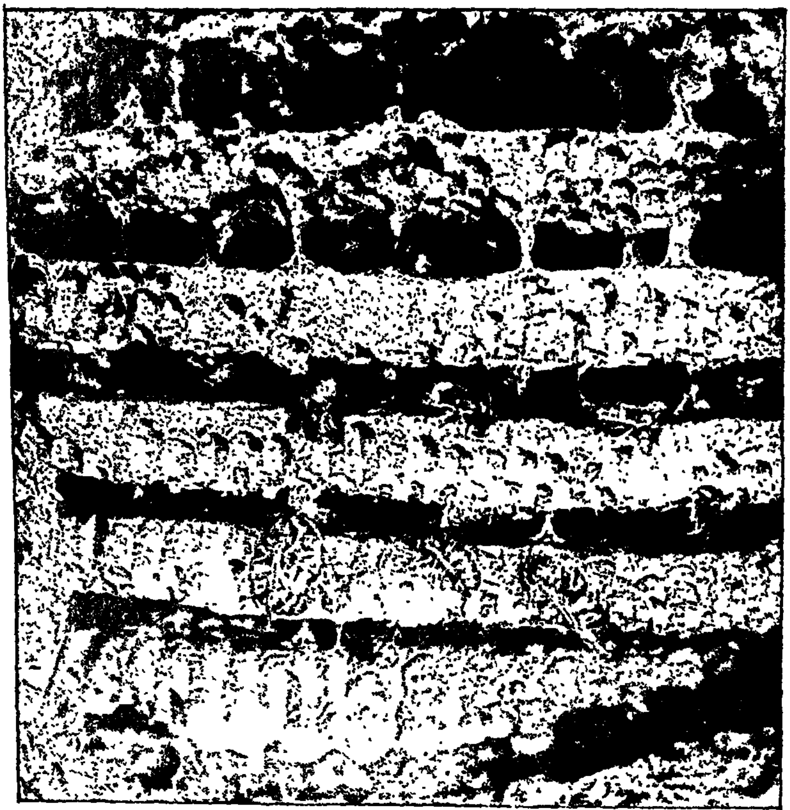


Photo: J. J. Ward.

INTERIOR OF A NEST OF ACTIVE WASPS.

On the bottom comb the dome-shaped queen-cells are seen, and on the comb immediately above are two young queens just emerged from the cells, with a male wasp resting on the comb between them. All above are worker wasps, tending the young and making new combs.

Photo: H. J. Shepstone.
AN ILLUSTRATION OF THE GARDEN OF GETHSEMANE BEFORE THE COMING OF THE LOCUSTS (see illustration below).

Photo: H. J. Shepstone.
THE GARDEN OF GETHSEMANE AFTER LOCUSTS HAD PASSED. EVERY FLOWER AND EVERY SHRUB WAS LEFT QUITE BARE.

the acquisition of wings, and one of the most marked differences between larva and adult is in most cases the difference in the food and the method of taking it. This is so great that the transition from larval to adult habits could not take place along with continuous external activity—the quiescent period of reconstruction is essential.

Photo: H. J. Shepstone.

AN ASIATIC LOCUST.

After several moults the locust is a perfect, winged insect. Immediately after the skin-casting it is soft and helpless, but a short time in the sunlight makes it firm and vigorous. The lower wings are fan-shaped, and fold up longitudinally under the longer, narrow and spotted outer wings.

§ 8

Insects and Man.

A great many insects live their busy days and perish without affecting man at all, except that they delight him with their exquisite colours and markings and interest him with their ways, but some are his friends, and perhaps more he reckons his foes. Even the Bee he too often shrinks from, remembering the weapon she carries and forgetting her honey and the infinite service she renders by securing the pollination of many flowers. The Termite may be as much a tiller of the soil as the Earthworm is, but she attacks his furniture and the wood of his house; the cochineal and "lac" that insects provide are relatively insignificant; and "locusts and honey" may be thought a dainty dish in the East, but a locust swarm will blight every green thing in a district. "He scatters the seed, and when he looks for green heads to appear, the earth opens, and, lo, an army of long-faced, yellow grasshoppers come forth!"

Locusts.

Wherever locusts are resident they do a great deal of damage, but it is their sudden migratory swarms which are so disastrous. They increase in numbers during favourable seasons; then, one year, when the food-supply is insufficient, they collect in immense swarms and travel long distances, devouring every green thing in their path. A tobacco-grower saw a swarm of locusts descend on a plantation of forty thousand young plants. Twenty seconds later not a leaf remained! The Old Testament speaks of the locust as one of the plagues of Egypt. "They covered the face of the whole earth, so that the land was darkened; and they did eat every herb of the land, and all the fruit of the trees which the hail had left: and there remained not any green thing in the trees, or in the herbs of the field, through all the land of Egypt."

In addition to the formidable list of insects, larvæ and adults, injurious to plants, another list must be added of those which affect the health of man and of his stock. There are a number of ways in which insects may affect the health of man. They may have poisonous bites or stings, as in the case of certain Bugs, Bees, Wasps, etc., which cause inflammation and sometimes feverishness; or they may be parasitic, either true parasites such as fleas and lice, or accidental parasites, such as fly-maggots, which sometimes reach the stomach and cause great pain; again, they may carry disease germs. Most important of all are the cases in which an insect is an essential host in the development of a disease-producing organism, without which the life-history of the organism cannot be completed.

For example, the Mosquito is not only the means of introducing into the blood of man the Protozoön which causes malaria, but the life-history of the malaria organism cannot proceed

without the insect; the different stages can only be reached within the bodies of man and mosquito respectively, so that the extermination of mosquitoes would wipe out malarial fever. In other cases, the insect is not necessary to the life of the disease-producer, but acts as a transmitter, as in the case of plague, where the bacillus is conveyed from rats to man by means of rat-fleas, which inoculate the victims while biting. Further cases of disease-carrying form another list—those of the simple carriers, such as the common House-Fly: it is not a blood-sucking insect, but it has a body and legs thickly covered with hairs particularly well suited for transferring germs, such as those of typhoid fever, from place to place, and it thus brings the microbes of the garbage heap to its next feeding-place, our dinner-tables. There is a long list of diseases in which insects play an important part—typhus fever and Lice, sleeping sickness and Tsetse Flies, relapsing fever and Lice, and many others. Many insects also affect the domestic animals, for example the "bot-flies" which cause severe boils and other disorders in cattle.

Such examples out of the list serve to show some of the complex inter-relations between man and Insects, and to indicate some of the aspects of the struggle for existence. Man's enemies are innumerable; he tames the wild beasts, and domestication brings its own penalty, for a sucking insect wipes out a whole herd; he exterminates great flesh-eating animals that would rival him, but a common house-fly brings microscopic germs to his table and spreads death through his cities. It is hardly too much to say that the tendency of injurious insects to prolific multiplication is a continual menace to civilisation, and this should lead us to attach increasing importance to the preservation of the numerous insectivorous birds which maintain the balance of Nature. But this subject will be discussed in a special article dealing with Inter-relations.

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XV

THE SCIENCE OF THE MIND

THE NEW PSYCHOLOGY—PSYCHO-ANALYSIS

IT is something of a paradox that the most difficult thing the mind finds to master is the mind itself. In recent years science has applied itself to the problem with a new keenness; much attention has been given to the special study of the mind of the child, and valuable results have been obtained from the study of animal behaviour. In particular there have been many investigators at work on what has become known as the New Psychology, which concerns itself largely with abnormal mental phenomena and subconscious operations —that part of mental activity which lies beyond the region of normal consciousness.

Practically all the recent work in psychology has gone to show that there are elements in our minds of which we are unconscious, and that these elements often take a greater share in shaping our behaviour than do the elements of which we are directly aware. The conception of the human mind has, in fact, undergone a profound change; it is revealed as a larger and more complicated affair than we had supposed, and we now see that what we had taken to be the mind is, in reality, a superficial although very valuable part of man's total mind.

The Senses.

Sense-experience forms the foundation of our mental life. In the course of long ages of evolution our sense-organs have evolved, and have given rise to that wonderful organ the human brain. It is through the senses that all the materials with which the mind builds up the higher forms of experience —memory, imagination, and thought—are obtained. For the senses are the Gateways of Knowledge.

It would be going beyond the scope of our subject to describe fully the evolution of our various organs of sense—the mechanism of the eye, the ear, and so on. By these instruments we are able to image and focus the world outside of us.

A sensation depends on some physical influence, the stimulus affecting some part of the outer or inner surfaces, or tissues of the body. In most cases there is a special organ adapted to receive the stimulus, and so to transform its action into a nerve-impulse for transmission to the brain, such as the eye, the ear, parts of the skin, and so on.

The acquisition of the sense of sight vastly enlarged the horizon and widened the mental range; and so with hearing, which is the most recently acquired of our specialised senses. We know that the senses are not infallible; they are limited and imperfect; but there is no evidence whatever that the development of our senses has reached finality.

The Brain.

The structure of the brain was briefly referred to in the section dealing with physiology. We need recall only that there are several main divisions of the brain, each with its own peculiar functions. The brain proper consists of the cerebrum, or larger brain, which occupies the whole of the upper and front parts of the cavity of the skull. It is divided into two great cerebral hemispheres, right and left, which are linked together by numerous nerve-fibres. The outer surface or cortex of the fore-brain is the seat of sensation and volition. It is a wrinkled or convoluted fold of grey cellular matter, which if smoothed out would cover a little over a foot and a half square. There are in the convoluted part of our fore-brain (the cerebral cortex) five or six times as many nerve-cells as there are human beings in the world, and the complexity of interrelations is past all telling.

The cerebellum, or lesser brain, lies at the back of the head, and below it is the medulla, whose functions have been previously explained. We need not, therefore, further enlarge on the outline of our nervous system—the cerebrum, cerebellum, brain-stem, spinal cord, and nerves. "That marvellous structure, the human brain, is the product of millions of years; its history

begins with life itself." The brain is a republic of nerve centres; each part has its own peculiar function—and all in inter-action. There are parts of the brain whose function is unknown —parts which we believe serve for memory, judgment, and imagination. There is reason to suppose that one part is the seat of the processes associated with remembrance of articulation; that another is similarly associated with memory of the sound of words; yet another part of the brain is associated with visual images of words and letters.

There is no lobe in the brain that is the seat of intelligence. It is the whole cortex, we might almost say the whole nervous system, or the whole body, that is concerned in intelligence, not any single region of it. It is by the plasticity, the power of adapting itself to new ways of learning, registering, and repeating new co-ordinations of actions, that the brain is marked out from the rest of the body and even from the rest of the nervous system. Great ability, great intelligence even, are not dependent primarily on the brain.

§ I

Mind in Evolution.

When we look back over the vaguely discerned evolution of Animal Behaviour, we find that it had its starting-point in the tentative movements of simple creatures, as has been explained in a previous chapter. We see such tentative movements in the very lowliest creatures (see p. 41).

At an early stage there must have been established a number of particular answers (involuntary muscular and nervous movements) to

stimuli, which became enregistered in the creature, and these ingrained capacities increase in number. We discern a persisting state of the organism which *varies* the answers; there is probably a simple expression of conation or endeavour. And in time we come to perceive something of purposive behaviour. "With the establishment of a nervous system there was opened up the possibility of a new kind of organisation—that of reflex actions and tropisms, which play an important rôle in behaviour, an organisation which heredity perpetuates." Reflex actions are automatic movements of nerve-cells and muscle-cells of lower animals, which secure a fit and proper answer to a recurrent stimulus. Tropisms are on a somewhat higher plane; they are forced or obligatory movements of the animal *as a whole*, that is to say, every creature of the same kind, and in the same physiological state, will behave in the same way. On a still higher level we have instinctive behaviour, "which reaches its purest expression in ants, bees, and wasps. In birds and mammals it is more likely to occur in co-operation with intelligence. Instinctive behaviour agrees with reflex acts in not requiring to be learned, in being dependent on hereditary nervous predispositions, and in being exhibited approximately in the same way by all similar individuals of the species." [1]

We have discussed previously the history of these progressive evolutionary advances, culminating in intelligent behaviour, and we saw wherein lay their survival value. We need not consider them further here. Reflex actions, tropisms, and instinctive behaviour have become part of the inborn *hereditary* constitution of all higher animals.

The question may be asked, what, besides what we call our mental faculties and our instincts, forms part of our natural inheritance; in other words, what comprises the innate constitution of the human mind? The question is not easy to answer. Dr. McDougall puts the question in the following form: "Does the native basis of the mind comprise any disposition, in addition to those which enter into the composition of the instincts; and if so, to what extent are they systematically linked together?

"We cannot answer this question with a negative. There is certainly much beside the faculties and the instincts comprised within the native basis of each human mind. If there were not, it would be impossible adequately to account for the vast superiority of the mind of the human adult to that of the highest of the animal. Some of those who regard the mind purely from the physiological standpoint, and who believe that all we have called the structure of the mind can be adequately described in terms of the organised structure of the brain, take the view that the superiority of the native endowment of man consists, chiefly or wholly, in the presence in the brain of the infant of a great mass of unorganised nervous tissue which offers unlimited possibilities of progressive organisation. But, even if we accepted the assumption that the structure of the mind can be wholly described in terms of nervous disposition and their connections, we could not accept the view that nothing of the mental organisation beyond the instincts is innate."

The bearing which all this has on our present problem is this: can we say that the particular kind of activity known to us as thinking, feeling, and willing is implicit in the germ-cell just beginning to develop into an organism of great complexity—an individuality in the one-cell phase of its being, a mind-body or body-mind telescoped down. It varies, it makes experiments, it makes its own essays (in internal re-arrangement) in self-expression.

"The germ-cell is a sort of a blind artist; its sketches are submitted to the criticism of the fully formed organism, the seeing artist, who will put them in the proper light and bring out what there is in them of value.

"If the amœba has in its small way a mind, an aspect of itself corresponding to our mind, and if the amœba uses it when it goes hunting—two not unreasonable hypotheses—then it may be that the germ-cell has also its analogue of mind—a not unreasonable hypothesis, since it develops into a creature with a mind." [1]

§ 2

It is not the province of psychology to explain what mind is; that belongs to the region of philosophy. Still, the great problem which holds an interest for us is concerned with

[1] J. Arthur Thomson, *The System of Animate Nature*.

the relation that exists between mind and body. Is mind independent and distinct from the body, or is it merely "an activity of the brain-cells, a product of nerve stimulation"?

Men have argued endlessly on the relation of mind and matter. To discuss, even briefly, the various theories—and there are many—would take a volume.

Mind and Matter.

Photo: Poulton.

ARISTOTLE.

The most profound thinker of the Ancient World. He has been described as the best educated man of any age.

What the precise connection between mind and body is, no one, as yet, has been able to say with any degree of certainty. On the *mechanistic* view as it may be called, the mind is a direct product of the brain, and has no separate independent existence. Every act of intelligence, every mental activity, is due to a physiological mechanism. Every thought "is the result of chemical or mechanical changes in the brain; an 'idea' is but an explosion or discharge of the brain-cell, an emotion is an activity of the brain bursting into flame; every feeling of love, aspiration, or fear can be explained as due to purely physical changes which produce the vapour of thought, or the aroma of virtue."

If it be held that during life "all mental processes have their physiological concomitants, it is clear that these physiological concomitants, namely, the molecular changes in the nerve-centre, would, if completely ascertained, afford an accurate index of the mental processes."

But no one has ever shown what the chemical or mechanical changes are by which thought and feeling are produced. Mechanism, as applied to mind, remains a mere hypothesis, an hypothesis, it may be added, to which philosophy gives no support.

Another view is that mind is a *separate existence.* The relation of the mind to body is, on this view, frequently held to be one of parallelism: the two series, mental and physical, are independent of each other, each runs its own course," as two railway trains running side by side on a double track, or two rays of light projected towards the same infinitely distant point, run parallel with *one another in time and space.*" There is no cross effect from one to the other; each is a closed system, with its own laws. When consistently held, this view does not carry us much farther than the first view; each point in the mental series must have its counterpart in the physical series; the laws that are established for the physical must also account for the psychical events.

A third view is *Animism,* the Soul-theory, the belief that there is an individual mind in each living animal body; that between the mind and its organism a vital relationship holds; that the life processes are both mental and physical; that the directing force in evolution is to be found in the minds of the individual organisms, the urge of feeling in the lower, the increasing strength of emotion and will, with the widening scope of interest and of thought, in the higher organisms. Many arguments can be brought forward both for and against this theory, but we cannot discuss these here.

There has also been much discussion of what is called *The Two-Aspect Theory,* to which biological facts incline many inquirers. The theory assumes a psycho-physical being—a reality which we know under two aspects; "we think of the organism as one; as, while it lives, an indissoluble psycho-physical being. . . . The living creature gives an account of itself in two ways. It can know itself as something extended and intricately built up, burning away, moving, throbbing; it can also know itself as the seat of sensations, perceptions, feelings, wishes, thoughts. But there is not one process, thinking, and another process, cerebral metabolism (vital processes in nerve-cells); there is a

psycho-physical life—a reality which we know under two aspects. Cerebral control and mental activity are, on this view, different aspects of one natural occurrence. What we have to do with is the unified life of a psycho-physical being, a body-mind or mind-body. The advantages of the two-aspect theory, if it is tenable, are that it does justice to the extraordinary intimate interdependence of what we may call 'mental processes' and 'brain-processes.' It regards them as two equally real aspects of the continuous life of the organisms. . . . The objective side is the body as a living whole; the subjective side, in Man's case, is the unity of mind."[1]

In these days the now old-fashioned materialism of the previous generation, as Mr. Bertrand Russell says, "receives no support from modern physical science if, as seems to be the case, physics does not assume the existence of matter." We saw in a previous chapter ("The Foundation of the Universe"), what the new view of the constitution of matter is. The atom of every element of matter is revealed as a particle of electricity; what electricity itself is we do not know. But we see how it comes about that the physicist tends to think of "matter" as less and less material. So does the chemist, and so the biologist. In that sense the old-fashioned "materialism" has gone.

The view of Mr. William James and others is that the "stuff" of the world is neither mental nor material, but, for the lack of a better name, a "neutral stuff," out of which both are constructed. Mr. Bertrand Russell, in his work *The Analysis of Mind*, endeavours to develop this view as regards mental phenomena. We cannot sum up the problem better than another writer who says: "Supposing we were able to understand all the phenomena—chemical, physical, physiological—of this intricate mechanism, we would be no nearer a solution of the problem of the connection between the objective and subjective impacts of the phenomena. . . . A philosophy which recognises both sets of phenomena—mental and physical—mutually adjusted and ever interacting, recognises the facts of the case, and does not delude the mind by offering a solution which is in reality no solution at all. The difficulty is somewhat lessened if we assume that behind all physical and mental phenomena there is a metaphysical essence, conscious or unconscious, and that the phenomena we term physical and mental are only different sides of the same kind. Such an essence can never be known to science, and the discussion of the possibility of its existence and of its properties belongs to the province of philosophy."

[1] J. Arthur Thomson, *The System of Animate Nature*.

§ 3

Psychology is the science of the mind, or more strictly, let us say, it is the science of the behaviour of living things; it includes the study of consciousness.

Mental Processes.

In the sense that the brain receives all those nervous impulses that result in consciousness, it would be true to say that the brain is the seat of consciousness. But that does not provide a solution of the problem of the origin of consciousness. "No one doubts that consciousness has a material substratum, but the problem of the relation between the mental state and the molecular movements on nervous matter is as far from solution as in the days when little was known of the physiology of the nervous system. The old-fashioned method was to assign to the mind certain so-called faculties—perception, conception, imagination, reason, will—to explain the operations which they denote. The mind has not its will here, its conscience there, and its reason somewhere else; it reasons, wills, and is conscientious as a whole. Thought, feeling, and will do not lie side by side, as it were, like stones in a mosaic, any of which could be removed without destroying the rest; they rather resemble the functions of the body, none of which are possible without the co-operation of all the others."[1]

Another way to describe mental activity was to regard every idea "as capable of existing in two conditions, or forms; on the one hand, it might be a conscious idea, or exist in consciousness; consciousness being spoken of as an illuminated chamber into which ideas enter in turn, to be lit up and active for a short period; and on the other hand, it might exist as an unconscious idea in the memory, a sort of Hades or dim underworld to which each idea, or its

[1] F. S. Granger, *Psychology*.

Photo: W. A. Mansell & Co.

SIR EDWIN LANDSEER'S PAINTING "A NAUGHTY CHILD."

A fine study that will suggest much to the student of psychology

ghost, returns after its brief exposure to the light of consciousness; there to await and to seize any opportunity of emerging again into light and life. Within this underworld ideas remain linked together in complex groupings. The whole assembly of ideas, thus linked in the obscurity of memory, constitutes the structure of the mind; and mental activity consists in each idea dragging up after it into the light whatever ideas are linked or associated with it."[1]

When we come to the mind proper we may, using a purely pictorial analogy, regard it as consisting of three layers. The top layer we may call the region of the conscious life. It is, as it were, a vividly illuminated region, where everything that goes on is clearly seen. It is to this region that we normally refer when we seek the explanation of our conduct, and, as we shall see, the explanations we obtain in that way are often wrong. A little below this clear region is a semi-conscious region, a region which can become accessible to us by effort. It is in this region, for instance, that the information which is not present to our minds, but which we *can* remember, may be considered

[1] Wm. McDougall, *Psychology*.

to be stored. Sometimes the contents of this region can be exhumed only by considerable effort, sometimes a very slight stimulus is sufficient. Beneath this layer, again, lies the region of the unconscious, and this region is, normally, quite inaccessible to our conscious mind. The description we have given is, of course, figurative, since we cannot suppose that the mind occupies space. But this division into layers is helpful in enabling us to understand the modern theories of the mind. The unconscious is the seat of the mental elements associated with the great primary instincts, and it is the great source of psychic energy. Of the activities going on in it we have no direct knowledge; we can infer something, however, as we shall see later, from observation, and more especially, according to some authorities, from *dreams*. The unconscious is the very basis of the psychic life of the individual.

The Importance of Complexes.

Mental phenomena never occur singly, but always in some complex combination or another. It will help us in understanding the nature of the mind to consider it as a *network of mental elements*. Every mental element, every idea as we say, which comes into the conscious mind, calls up others. There are *associations of ideas*, to use the language of the older psychologists. It is because ideas are associated that we are able to go about our daily lives. If no ideas suggested any others, or if others were suggested purely at haphazard, we should never be able even to cross the road. A number of mental elements associated together so as to form some more or less loosely knit system is called a complex. To some men, for instance, the sight or sound of a typewriter may always, or usually, suggest to them an office; the smell of a certain flower may always bring back some early experience, and so on. Associations of this kind—associations of ideas, as it were—are called *complexes*. We may think, if we like, of ideas forming groups, and the whole of the contents of the mind as made up of groups of ideas—*complexes*. Further, complexes vary enormously in the emotional energy associated with them. Besides the great number of minor complexes brought about by a man's education, the nature of his work, and so on, there are so-called universal complexes. These are the complexes which centre round the three great primary instincts, or groups of instincts, and they are known as the sex-complex, the ego-complex, and the herd-complex.

Complexes which directly centre round a great primary instinct such as sex are associated with a great fund of emotional energy. The actual mental elements present in the sex-complex of any particular man, besides depending on inherited characteristics, depend also on his personal history. The ego-complex, associated with the primary instincts of nutrition and self-preservation, has most of its elements beneath the conscious level; and the same may be said of the herd-complex, which depends upon the gregarious instinct in man, and which plays an enormously important part in his life, as we shall see.

Amongst the three great universal complexes the ego-complex is the oldest and most profound. This is the complex with which is associated man's recognition of "his self." This very powerful complex may give rise to all sorts of unpleasant manifestations, to various exhibitions of greed and of the desire of self-aggrandisement; but it also gives rise to some of the most beneficent of man's activities. Amongst these we may mention the desire for *construction*, for the making of something which is a personal achievement, whether it be a house, a poem, or a system of philosophy. The desire to construct has certainly been one of the most potent factors in human advancement.

The Herd-Complex.

The second great universal complex is the herd-complex, and this, as we have already said, depends upon the fact that man is gregarious. We do not know at what point in man's development he first developed the gregarious instinct. It must have been quite early, however, that man began to live in association with his fellows. The advantages bestowed by gregariousness are obvious. But the instinct of gregariousness brings with it certain consequences which are of the utmost importance in the psychic life of man. This instinct brings with it great *suggestibility*. The individual, as a member of the herd, must be very suggestible to impulses coming from the herd, in order to act in harmony with it.

He must be able to yield unquestioning obedience to the voice of the herd. In the case of man his rational faculty, combined with his suggestibility as a gregarious animal, leads to the most diversified manifestations. The great bulk of man's opinions are in reality strictly non-rational, and are products purely of herd-suggestion; but that does not prevent him rationalising them. Many of them he does not trouble to rationalise. They appear to him "obvious"—as obvious as that good food is desirable; they come with *instinctive* force. The moral code in force in a community furnishes a set of beliefs of this kind. This set of beliefs changes from time to time and from country to country, but whatever set of beliefs may be in vogue in any particular community at any particular time is "obviously" right.

Photo: L. E. A.
THE LATE PROF. WILLIAM JAMES.
Professor of Psychology at Harvard, and investigator of psychic phenomena in America.

We cannot consider in detail the manifestations of the three great groups of primary instincts, but we may discuss, for a moment, two types, in one or other of which nearly every human being can be classed. These two types of human beings are called by Mr. Trotter the *stable* and *unstable* types.

Two Main Types.

The *stable* type is the type which is often described as forming the backbone of the country. A man of this kind is energetic, strong-willed, and full of settled convictions. He is perfectly at home with the laws and traditions of the community of which he is a member. His aims are of the kind that the community as a whole can understand and approve, and he is steadfast in his pursuit of them. He has decided views on moral questions, and on political and any other subjects. He is never in doubt as to what is right and what is wrong.

Photo: Elliott & Fry, Ltd.
DR. WILLIAM McDOUGALL.
Professor of Psychology, Harvard University, author of several important works on psychology, including *Body and Mind, a History and a Defence of Animism.*

The great drawback to this type is its insensitiveness to experience; it is incapable of surveying any question from an entirely fresh standpoint. Indeed, it is apt to regard the searching questioning of accepted and established things, such as a code of moralities or a system of politics, as either foolish or wicked or both. Great changes in current practice and ideas, however desirable such changes may be, cannot be effected by the class of people—and it predominates in numbers—which has the strong prevailing gregarious instinct—in other words, in which the herd-complex is strongly engrained.

The *unstable* type has qualities almost exactly opposite to those of the stable type. Thus, a man of this type has very few settled convictions, although he may have plenty of enthusiasms. He can easily be won to a new cause, and he as easily falls away therefrom. He may undertake a number of projects, but it is unlikely that he will persist with any one of them long enough to carry it to a successful conclusion. He has what is called a weak will, and he can by no means accept the ruling of the community on all questions. His great positive merit is his sensitiveness to experience, and, indeed, it is from this that all his trouble springs. He is always changing his mind because he is always open to fresh impressions. He is, usually, the intellectual superior of the stable type, although the stable type often despises

him. But each type has its great disadvantage, and neither represents what a human being could and should be.

The fact that different complexes may be incompatible with one another leads us to the important question of *conflict*. A perfectly healthy mind is a mind which has established complete harmony between its different complexes. But the perfectly healthy mind, in this sense, is very rare; we usually find that several of a man's complexes are incompatible with one another, and on those occasions when more than one are aroused there is *conflict* between them. Thus it may often happen that a man's "selfish" desires, those springing perhaps from his ego-complex or his sex-complex, conflict with the moral code of the community, a code which has great weight with him because it is associated with his herd-complex. Such conflicts are favourite themes for novelists: the father torn between patriotism and his love for his son; the intending monk torn between his religion and his love of his family; the man torn between an illicit love passion and his sense of morality. Conflict plays a prominent part in the psychic life of most people, and it leads to very important consequences. For the conflict must be settled, and there are two very important ways of settling it. There is the method of *rationalisation*. One of the conflicting complexes is allowed to triumph, but not consciously. Reasons are invented for the resultant action which have nothing to do with its psychic causes, but which prevent the man from feeling "ashamed" as we say. Thus a primitive brutal desire for revenge may be disguised as justice. An exhibition of ruthless greed—as in some unscrupulous business deal, for instance—will be explained by pointing out that it is for the good of the community that its most efficient citizens should come to the top, and so with other conflicts.

Conflicts.

Another very important method of settling a painful conflict is by *repression* of one of its factors. It is this method which has been chiefly studied by Freud, and he has succeeded in showing how very great its importance is. A man decides completely to ignore one of the conflicting complexes—he puts it out of his mind. But, as Freud has shown, the ignored complex is not thereby destroyed. It is repressed into the unconscious, but it is still energetic and may manifest its existence in a number of ways, ranging from certain phenomena of *forgetfulness* down to hysteria and insanity. It may happen, for instance, that the repressed complex leads to a certain kind of forgetfulness, a forgetfulness of those things with which it is associated. A man may forget an appointment from which he anticipated something unpleasant, he may forget the existence of unpaid bills. Such cases are cases of *active* forgetting, and are to be distinguished from cases of *passive* forgetting, where the matter is forgotten simply because it made very little impression on the mind. A slip in speaking or writing may sometimes testify to a repressed complex; the substituted word corresponding to a wish, but a repressed wish, of the speaker or writer, as when the President of the Austrian Lower House announced that the sitting was closed when he should have said it was opened, the reason being that he privately expected no good from the sitting and would have liked it closed.

§ 4

PSYCHO-ANALYSIS

A comparatively new branch of psychology is that closely associated with the work of Professor Freud of Vienna. It deals mainly with the phenomena of the unconscious. Whatever may be said of Freudian theories, they have at least opened up a wide field of study. Part of Freud's doctrine has become fairly well established; on the other hand, a great deal of it is regarded as merely ingenious theory, which is not generally accepted. This "new" psychology is of very great interest, because of the bearing it has on medical practice and the work of the teacher.

Professor Freud's Theories.

The chief theory of the Freudian psychology is, that there is a great part of the mind of which we are unconscious; that this unconscious part exercises an enormous influence upon our thoughts and actions, without ourselves being aware of it. Freud conceived the idea that the influence of the unconscious mind was especially active as a cause of dreams, and thus

he was led to his now familiar theory of the interpretation of dreams.

The work of Professor Freud, his disciples and his critics, has thrown a flood of light upon the working of the human mind, and led to curious alterations of our views upon dreams, insanity, myths, art, and religion. In dealing with patients who were suffering mainly from functional diseases of the nervous system, Freud found that what had been regarded as the symptoms of the disease, such as paralysis of the limbs, blindness, deafness, and mutism, were frequently connected in some definite way with the original onset of the disease; blindness, for example, might date from some violently painful occurrence of which the patient had been a witness. This connection was not as a rule recognised by the patient's waking consciousness, but it revealed itself occasionally to the doctor when the patient was hypnotised; sometimes also it was brought out by the dreams which the patient described; but in general the ordinary consciousness of the subject resisted all attempts to probe back to the original cause of the disease.

PROFESSOR FREUD.
The "New Psychology" is closely associated with his name. His doctrines are explained in the section dealing with Psycho-analysis.

Turning his attention to dreams, Freud found that in the case of normal individuals also there were painful experiences, never revived in the fully conscious mind, but playing a great part in the dreams of the subject, appearing there in a more or less disguised form; and that the interpretation of the dream in both normal and abnormal subjects invariably led back to some wish or desire of the individual, which it was impossible for him, for physical, moral, or social reasons, to realise in waking life. The dream was the mimic realisation of the wish.

The instinctive or voluntary forgetting, Freud called Repression; the repressed ideas were not, however, destroyed, but were constantly endeavouring to force their way back into consciousness. He gave the name of the "unconscious" to the mass of repressed memories of all kinds. For the repression of a wish involves also the repression of the whole system of experience to which the wish belongs; hence, for example, the fact that we can rarely remember our infancy-time at all.

The Subconscious.

We have all some experience of what is called *subconsciousness*; an idea, as it passes to and from the focus of consciousness, gradually becomes clear and vivid, then fades away into dimness and vagueness, till it is merged in the general mass of feeling and loses all distinctiveness; a word is "on the tip of the tongue," later it is clearly thought and spoken. I have an appointment to remember, I do not think of it for hours, and then—in good time, perhaps—it walks into my "consciousness." I resolve to awake at six in the morning, and—if my mind is of the right kind—as the clock strikes six, or just before it, I awake. These are different cases in which an idea, a thought, is apparently not in consciousness, and yet not wholly out of it. The term "subconsciousness" has been used for this class of phenomena, where, apart from the "dominant" or "personal" consciousness, certain strands of experience, which have once been conscious, continue somehow to live, and in due time make their influence felt in the dominant consciousness.

The theory of Freud is, that in the unconscious part of the mind there lie dormant memories of the past and especially "repressed" impulses. These repressions represent the resistance we make to a wish or impulse which we think we ought not to satisfy, because it conflicts with some other interest; or they mean the effort we make to put out of our mind some unpleasant memory. The effort to repress may not be deliberate, it may be unconscious repression. In any case there may be a repression to such an extent that the memories pass entirely from us, or as it is held, they are pushed deep into the unconscious, where they continue to exist. We are asked to believe that "the unconscious includes many impulses and memories which remain buried in the depths of the mind," and that they persist in trying to return to the living mind. Further, it is said that to some extent they do so, influencing the mental life even

although we are not conscious of the influence at work. In this way repressed tendencies are supposed to get a partial satisfaction.

§ 5

The records of medical men in their work connected with nerve cases in military hospitals during the war has provided much material for the study of abnormal psychology of this kind. Cures of paralysis of various organs, of morbid obsessions, and unreasonable fears have been recorded and described by responsible members of the medical profession. The origin of many mental troubles has been traced to repression of disturbing emotional experiences, bygone and forgotten by the patient. The recalling or revival of such lost memories of patients by medical men skilled in psychopathology have, by clearing the mind of the patient, enabled physicians to effect many striking cures of mental disorder.

Cases of Mental Disorders.

The theory is that the bringing to light and the re-living of the suppressed emotional experiences is a means of getting rid of excessive emotion. The patient is enabled to assume a new attitude towards them. By way of illustration we may give one instance:

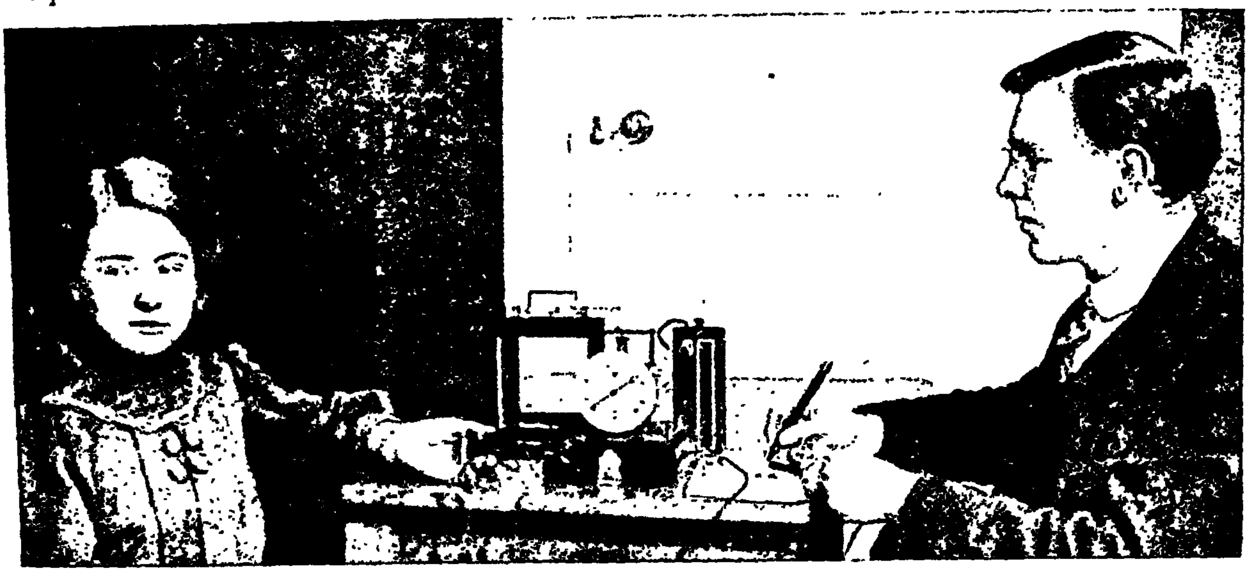
The following case of the influence of forgotten experience is described by Dr. W. H. Rivers in the *Lancet*, and we take this excellent summary of it as given by Professor Valentine in his *Dreams and the Unconscious*.

" It is the case of a young medical officer, who even before the war had a horror of closed-in spaces, such as tunnels and narrow cells. He would never travel by the tube railway, and was seized with fear in a train which passed through a tunnel. One can imagine his intense distress when on entering a dug-out he was given a spade and told it was for use in case he was buried alive. His sleep was greatly disturbed, and his health became so bad that he was invalided home. Instructions to keep his thoughts from the war and to dwell exclusively on pleasant topics proved useless. He had terrifying dreams of warfare, from which he would wake, sweating profusely, and thinking he was dying. At this stage he came under the care of Dr. Rivers. The patient was asked to try and remember any dreams he might have and to record any memories which came into his mind while thinking over the dreams. Shortly afterwards he had a dream, and as he lay in bed thinking it over there came into his mind an incident which seemed to have happened when he was about three years of age, and which had so greatly affected him at the time that it now seemed to the patient almost impossible that it could ever have been forgotten. He recalled that, as a little boy, he and his friends used to visit an old man in a house near his own, and to take him odd articles discarded at home, in return for which they received a copper or two. On one occasion he went alone, down the long, dark passage leading to the old man's home, and on turning back found that the door at the opening of the passage had banged to, and he was unable to escape. Just then a dog in the passage began to bark savagely, and the little child was terrified, and continued so until he was released. After another dream the patient woke up to find himself repeating " McCann! McCann! " It occurred to him, suddenly, that this was the name of the old man. Inquiry of the parents of the patient revealed the fact that an old rag-and-bone man had lived in such a house as the patient remembered, and that his name was McCann.

" The result of this recovery of memory, with the explanation of his abnormal fears of closed-in spaces, had a great effect on the patient. A few days afterwards he lost his fear of closed-in spaces, and he afterwards travelled in tube railways and tunnels without discomfort. Indeed, he was so confident of himself at once that he wished Dr. Rivers to lock him up in some subterranean chamber of the hospital as a proof of his cure. The particular point to be noticed here is that an entirely forgotten experience continued, apparently, to have an influence upon conscious mental life. Other points of interest are these: that the original experience was an intensely emotional and disturbing one; that the experience was recalled through reflecting on a dream; that the conscious effort of will to banish the unreasoning fears had no effect; that the fearsome experience, though repressed until forgotten, found its way out to consciousness through the repeated emotions of fear. This constant fear

was stimulated by being in closed-in spaces, that is, by situations similar to the original one, though that was forgotten."

There are many such cases as this on record. A great deal of work has been done on similar lines, and the study of disorders of various kinds, having a mental origin, has been put on a scientific basis within the last few years. This is not the place to describe the methods of the practitioner; the principles followed depend on individual cases.



MR. CYRIL BURT, PSYCHOLOGIST TO THE LONDON COUNTY COUNCIL, MEASURING THE SPEED OF THE THOUGHT OF A CHILD WITH A CHRONOSCOPE TO TWO-HUNDREDTHS OF A SECOND.

§ 6

Dreams.

Much, probably far too much, has been made of the claim that psycho-analysis may be applied to the interpretation of dreams. The starting-point from which Freud's theory was developed was the interpretation of dreams, based on the assumption that dreams are the symbolical expression of repressed tendencies. To claim that every dream is determined by the subconscious working of a repressed tendency is unwarrantable, and the theory is not accepted by those most qualified to speak on the subject. On the other hand, it would be an extreme view, as Dr. William Brown says, to deny all meaning to dreams, and regard them as merely the confused and jumbled reappearance during sleep of memories belonging to the person's past history, strung together in any chance order.

The recent work on dream analysis, however, has added immensely to our knowledge, and we now possess a theory which undoubtedly covers a very large part of dream phenomena, even although it certainly does not cover the whole. This theory is, briefly, that a dream is the symbolic fulfilment of a repressed wish; the wish has been repressed because, for one reason or another, its appearance in the conscious mind is attended with pain. But, as we have seen, repressed elements do not lose their vitality; they continue to work and they endeavour, as it were, to manifest themselves in some way or another. Now during sleep the barriers between the conscious and the unconscious are to some extent relaxed. Elements which are ruthlessly repressed in the waking life are now subjected to a less severe repression. But these elements cannot emerge in their naked purity, as it were; they exhibit themselves in a disguised form, often of the most fantastic description. In this way the wish secures a partial satisfaction. In his book on *The Interpretation of Dreams*, Freud gives a large number of such cases of symbolic fulfilment, and explains the technical processes by which these dreams are related to forgotten episodes in the life of the patient. Many of these cases are more ingenious than convincing.

Not all dreams are due to repressed wishes. Many dreams are more or less inchoate reproductions of impressions received during the day; such dreams, however, have a fragmentary character. In very many cases where the

dream is a rounded and completed whole it is also an allegory, a symbolic manifestation of elements which have been repressed into the unconscious. The repressed elements, even so, do not secure complete fulfilment. Repression is still operative, although it is relaxed. There is still what Freud calls the 'censor." Dreams may illustrate very interestingly, in fact, the indirect ways in which psychic energy seeks an outlet, when direct satisfaction is for some reason or other denied it. Many works of art are similar to dreams in this respect. In some cases of very deep and powerful repressed complexes, a dream fulfilment may not be satisfactory. An actual pathological condition may be set up; hysteria, insanity, and dissociations of personality, as in certain well-known cases of double personality, may be caused by the repressed complex. Many cases of this kind were brought into being by the terrible psychic strains of the war.

It is admitted that a certain class of dreams may be possible of interpretation, but we cannot discuss the subject further here; it cannot be accepted that Freud's theory of repression accounts satisfactorily for all dreams.

Another view is that which regards dreams in quite a different light. Dr. William Brown puts it in these words: "The function of a dream is to guard sleep. Sleep is an instinct like fear, flight, and the rest, and has a function which has developed in the course of evolution. At night this instinct of sleep comes into play, but it finds itself in conflict with other instincts and tendencies, as well as with external impulses. Desires, cravings, anxieties, the memories of earlier days, all of which are the lower and fundamental elements of the mind, well up and strive towards consciousness, while the main personality is in abeyance. If they reach consciousness sleep is at an end, but the dream, which is a sort of intermediary form of consciousness, intervenes, and makes the impulses innocuous, so that sleep persists. This theory covers the entire ground of all types of dreams."

There are other aspects of abnormal psychology which imply subconscious operations with which we have not dealt. The subject of telepathy, clairvoyance, materialisations, and other phenomena which appertain to psychic experience will be discussed by Sir Oliver Lodge in the following chapter.

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